A SAMPLING MODEL FOR THE ESTIMATION OF JUVENILE SHRIMP FISHERY OF VEMBANAD LAKE

DISSERTATION SUBMITTED BY

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CERTIFICATE

This is to certify that this Dissertation is a bonafide record of the work carried out by Shri. Anil, M.K. under my supervision and that no part thereof has been presented before for any other degree.

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C O N T E N T S

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PREFACE

Fish has been an important source of protein for the underfed population inhabiting in the coastal belt of the country. Realizing the importance of fishery resources in meeting the food requirements of the country, in recent times, developmental agencies have paid serious attention for exploiting these resources for the benefit of the population. Besides meeting the internal requirements, export of marine fish earns to the nation foreign exchange of about 630 crores of Rupees currently. Export of marine products from the nation has been mainly concentrated on prawns and its products. However, in recent times it is reported that in spite of increased inputs in fishing, the production of prawns is not showing commensurate increase. Hence industry and developmental agencies are seized of the problem of increasing production and ways and means of conserving the resources is being discussed in various forums.

Vembanad lake is well known to be an important nursery ground for commercially important species of marine prawns *Viz*. *Metapenaeus dobsoni*, *M. monoceros*, *Penaeus indicus* & *P. monodon*. These species of prawns spend their juvenile stage in backwaters and for attaining maturity they migrate to deeper regions of the sea. Traditionally these juveniles have been exploited inflicting juvenile mortality on these resources which otherwise would have supported a prominent marine prawn fishery in the country.

There has so far been no authentic assessment of the quantum of juvenile prawns exploited annually from Vembanad lake. Planning the conservation strategies in respect of these species would, needless to say require quantified information on this aspect of the problem. No attempt has been fruitfully made so far to investigate the exploitation to arrive at an assessment. No agency is known to have made any study to evolve a suitable and scientific method of collection of relevant data in this respect. Hence this study was undertaken to evolve a scientific method of collection of data on the catches of juvenile prawns from Vembanad lake.

Based on the study conducted sampling models were evolved to estimate the catches from stake nets and dip nets. It is needless to say that reliable statistics are a prerequisite for any management programme.

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INTRODUCTION

The marine prawn resources of the country are indirectly related to the vast brackishwater ecological system constituted by various estuaries, inland bays, lakes and backwaters along the entire coastline. In addition to the permanent inhabitants of the area, many fishes and invertebrates of marine origin including prawns temporarily utilize this biotic niche for completing their life cycle.

The commercial marine prawn fishery which has relationship with brackishwater environment is specific with a group of prawns belonging to the family Penaeidae in which are eggs are shed into water unlike other group of caridean prawns whose females carry their eggs under the belly till a comparatively advanced stage of development. As a rule the penaeid prawns of commercial importance are found closely associated with the shallow brackishwater environments. Nearly 35 species of these groups of prawns, with varying geographic distribution, support important coastal fisheries in different regions of the world. The penaeid prawns of commercial significance in India include nearly a dozen species, the most important among them being *Penaeus indicus*, *Penaeus monodon*, *Metapenaeus dobsoni*, *Metapenaeus affinis*, *Metapenaeus monoceros*, *Metapenaeus brevicornis*, *Parapenaeopsis stylifera*.

From biological as well as conservation points of view the interesting feature in the case of these species is that most of these penaeid prawns have a peculiar life history characterized by a period of more or less predictable length which is passed of in an estuarine or brackishwater environment. In most of these species the parent population breeds in the sea at various distances from shoreline, producing large number of microscopic eggs which are shed into the sea. These semi-buoyant eggs quickly hatch into small planktonic larvae known as nauplii. Matamorphosis takes place rapidly through protozoeal and mysis stages, all the while being transported towards the shore, especially towards mouth of rivers or opening of shallow lakes and backwaters. Depending on species, the time taken between the hatching in off shore waters and entry of small post-larvae into the brackishwater, varies usually from 2 to 4 weeks. In certain species they arrive in these shallow areas in the late larval stages while in some others they arrive in the early post-larval stages. Once in the brackishwaters, they leave the planktonic existence and descend to the bottom, reaching different parts of shallower waters. Over the subsequent 6 to 9 months they grow rapidly and reach certain sizes, varying with species. After these sizes are attained they return to the sea where the life cycle is completed. Considerable variations occur among the commercial penaeids, both in degree to which the brackishwater environment is utilized by each species in the life history and in the distribution of parent and juvenile populations in the gradient zones of brackish-water environment. The biology of Indian penaeid prawns of commercial importance, particularly of south-west coast have been studied in detail (Menon 1951, 1953, 1954, 1955, and Panikkar and Menon 1955).

Kerala is endowed with an expansive body of brackishwaters, the various sections of which are referred to as backwaters, lakes, lagoons and estuaries including mangrove swamps. From south to north they are named as Veli, Kadinamkulam, Paravoor, Ashtamudi, Kayamkulam, Vembanad, Cranganore, Valiyangadi, Korapuzha, Valiyapattanam and Kavnai. This chain of backwaters on the coastal plane are interconnected by extensive network of canals which facilitates transport of men and materials. These backwaters play a significant role in socio-economic and cultural life of Kerala. Vembanad Kayal, the largest backwater system on the west coast has an area of 36,500 ha. in the last century. It has undergone manmade shrinkage at an alarming rate by bunding and reclamation for agriculture, aquaculture, harbour and urban development and for other uses. As a result, at present only about 35% of its original area remains as open brackishwaters and out of which about half has been identified suitable for developing aquaculture farms in coming decade. This shows that only about 17% of Vembanad lake system will be left as open brackishwater by the dawn of 21st century, provided it is not further encroached for other purposes (Gopalan et al., 1983).

Vembanad lake extending between Allapuzha and Azhikode is a typical estuarine system and largest of its kind in west coast of India and is believed to have attained its present configuration in 4th century A.D., according to historians (Anon, 1973).

It was primarily a marine environment, bounded by an alluvial bar parallel to the coastline and interrupted by the Arabian sea at interval. As a result of a catastrophic deluge which took place in 1341 A.D., parts of Allapuzha and Ernakulam Districts including a number of islands arose, thus separating a distinct water body from sea with connecting channels at Thottapally, Adhakaranazhy and Cochin (Menon, 1913).

The life history of most valuable commercial sea-foods of Kerala like, *Penaeus indicus*, *P. monodon*, *Metapenaeus monoceros*, *M. affinis*, *M. dobsoni* involves an estuarine phase, as their post-larvae and juveniles migrate to estuaries which provide their nursery grounds. From time immemorial, a rich juvenile shrimp fishery existed in the low saline upper reaches of the estuary. Estuarine dependent species contributed to bulk of India's marine shrimp landings in the initial stages of development of export trade (Banerji, 1969).

Prior to the commissioning of Thanneermukkom bund, an average daily catch of 5 tonnes of shrimps was available during the summer months (Kannan, 1979). The bund has reduced the extent of backwater nursery grounds by 25%, which led to the total collapse of juvenile shrimp fishery of this region (Gopalan et al., 1983).

The decrease in area of the backwaters and increase in the demand for shrimp has resulted in a more intensive exploitation of backwater nursery grounds (Menon, 1967). This has probably led to the shortage of shrimp seeds in the estuarine farms, in which, rate of production has been progressively declining during the past 3 decades.

Various types of nets such as stake nets, chineese dip nets, drag nets, cast nets and indigenous devices like 'Pachil' (Panikkar, 1939; Menon, 1951; Gopinath, 1953; Panikkar and Menon, 1955) are made use of in capture of prawns; but the stake net and dip net catches are comparatively more abundant and may account for a substantial part of the total.

Reliable statistics are lacking about the total production and it is difficult at present even to make an approximate estimate of the magnitude of annual catch due to lack of data. It is needless to say that reliable statistics are a prerequisite for any management programme. Management of the backwater prawn fishery is very important because of its functional relationship with the marine prawn resources and the role, it plays in socio-economic condition of the inland fishermen.

MATERIAL AND METHODS

Vembanad lake where detailed investigations were carried out in present study stretches between Kodungalloor in north to Allapuzha in south encompassing an area of 256 Sq. Kms. (Shetty, 1963). That lies in between latitude of 9°10' and 76° 29' E.

Northern part of the backwaters above Aroor is generally referred to as the Cochin backwaters, while the southern portion is termed as the Vembanad backwaters. Northern portion of the lake is narrower and southern portion is broader. Lake is connected to the sea mainly at two places namely Cochin and Azhikode. Intense fishing activity for prawns using stake nets and Chineese dip nets take place only between Azhikode and Thanneermukkam where adequate tidal force is felt. The fishing is not active to the south of Thanneermukkam bund due to the lack of tidal influence as a result of the construction of bund across the lake to promote paddy cultivation.

The fresh water discharge from rivers like Periyar and Chalakudy on the north and Pamba, Achankovil, Manimala, Meenachil, and Moovattupuzha in the south make the backwaters typically estuarine. Since both connections to the sea are situated in northern half of the backwaters, that section is much more saline than the southern half of the backwaters. Water above Chembu- Panavalli area upto Azhikode has a salinity varying from 23.31% to 33.35% with maximum at Cochin. During monsoon season the salinity may go down sharply. In regions below Vaikom there is a gradual decline south wards from about 18% at Vaikom down to about 10% at the southern most end of the lake off Allapuzha. Water becomes almost fresh and is in a flooded condition from June to September during the south-west monsoon and the water level falls considerably after north-east monsoon during November and December when the water in distinctly brackish.

In the lake, the tides are of mixed semidiurnal type. Various environmental features such as temperature, salinity, dissolved oxygen, pH, seston, nutrients, alkalinity and chlorophyll are greatly influenced by tidal rhythm (Qasim and Gopinathan, 1903). The surface salinity fluctuates from 1.40 to 33.51% and surface temperature falls within a range 28-31 C with an annual fluctuation of 3 to 4 C.

There are more than 120 species of phytoplankton (excluding nano plankton) commonly occurring in the lake. Two peaks of phytoplankton abundance were observed-one coinciding with the enrichment of water during monsoon (May-July) and the other during post-monsoon (October-December). Low salinities and high concentration of nutrients lead to an abundance of diatoms and low concentration of other phytoplankton. Crustaceans constitutes more than 90% of the total annual zooplankton counts.

FISHERY

Although more than a dozen species of prawns are known to occur in the lake, among these major commercial importance contributing to rich fisheries may be mentioned four species, namely, *Metapenaeus dobsoni*, *M. monoceros*, *Penaeus indicus* and *P. monodon*. In general, the occurrence of prawns is fairly good in salt water side of the lake upto the barrage but beyond this area they show sudden decline. Among the four species of prawns *Metapenaeus dobsoni* is the most dominant one occurring in the lake. It is found to be distributed at all salinity gradients on either side of the barrage. During monsoon period a moderate fishery is observed for *Macrobrachium rossenbergii*.

Fin fish fishery of Vembanad lake comprise mainly *Etroplus suratensis*, *Mugil cephalus*, *Liza* spp., Hemirhamphids, *Brachiurus* spp., *Tachysurus subrostratus*, *Lates calcarifer*, *Lutianus argentimaculatus* and *Wallago attu* in the order of abundance. However there appears to be considerable change in the distribution pattern and abundance of finfishes on either side of the barrage which was non extant before the barrage became operational. The catches from northern zone comprised fishes of a heterogenous nature. Even in summer period the occurrence of typical estuarine species like *Salar malam*, *Gerres* spp., *Leiognathus* spp., and *Lutianus* spp. are restricted to northern zone.

The molluscan fishery resources are mainly represented by three species Viz. Villorita cyprinoides, var. cochinensis and var. cornucopia which support a large scale lime shell fishery in the area.

FISHING METHODS EMPLOYED FOR PRAWNS

Several types of gear are used to catch prawns in Vembanad lake. They can be classified mainly under 3 heads:

I) Fixed type of nets

II) Free nets

III) Others.

I. Fixed nets: Nets in this group are fixed to some permanent structures like stakes or frame at the time of operation. Important nets under this group are stake nets and dip nets, which contribute to the most important commercial fisheries of northern half of backwaters.

a) Stake net (Kuttivala, Unnivala, Valuvala)

The stake net is a long tapering conical bagnet of 15 m length and 18 m circumference, made up of either cotton or nylon thread and mouth is strengthened by a coir or nylon rope. At the mouth region the mesh size is about 20.5cm followed by 11.5cm and gradually decreasing to 3.8 cm and 1.28 cm. There are 4 coir loops at four corners of the net in the mouth region for fixing the net to a pair of poles or stakes driven into bottom mud. Cod end can be tied up with a piece of rope.

PLATE I- A ROW OF STAKE NETS

Operation: The net is operated only during the ebb tide in order to prevent the destruction of young ones of prawns entering the backwaters. Depth of operation vary from 3 to 5 metres and fishing goes on practically through out the year.

Net is fixed in such a way that the lower part or foot rope touches the bottom and head rope little below the water surface (this is to prevent the entry of floating debris into the net). Usually a pole is used to push the loops down along the stakes. Net is set against the tidal flow soon after the ebb tide has set in. Net will remain in operating condition till there is enough tidal flow to keep the prawns flowing into the net. Net is hauled out before the tide reverses; otherwise the catch may flow out from the net.

Actual operating time is between 3 p.m. and 10 a.m. Nets are operated from Ekadasi in both phases of moon and may last upto 5 to 6 days after new moon and full moon. Some times nets are operated through out the month without interruption in regions near the bar mouth. When the catches are very good, operations are done in both evening and morning time. Every day the time of operation will change by about 45 minutes. That is, if a day operation starts at 5 p.m., the next day the operation will begin at around 5.45 p.m.

According to Menon (1955), stake net fishery remains suspended when there are high floods during monsoon months (June to August), because of likelihood of swift current and floating debris damaging the nets. The catch obtained from an operation may vary from 200 gm to 20 Kg.

Two persons and a small boat are required for the operation.

b) <u>Dip net</u>: (Chinese dip net, or Cheena vala or Kamba vala)

It is a fixed balanced liver dip net, located singly or in groups both along the shore and near shore in shallow waters. Size of the net depends on the size of the frame work. Larger ones are used in the bar mouth region and smaller ones in interior areas. Its structure has been adequately described by Hornell (1937) and Panikkar (1937). The greatest concentration of this nets are found at and adjacent to the two openings of the lake into the sea at Ernakulam and Munambam region.

The net looks like a square piece. But it is a small bag net with a wide square mouth. The mesh size varies in different parts (20mm, 18mm, 10mm and 7.5mm, from mouth region to cod end). Net is made up of either cotton or nylon thread.

The frame work for attaching the net is made up of teak or Punna. The teak is costly but it will last for about 6 to 7 years.

Two to Four persons operate the net but a small net generally requires only 2 persons. A small boat is required for fixing and

PLATE II - DIP NET

PLATE III - A CLUSTER OF DIP NETS

removing the net. For prawns, it is operated only during night. A petromax or electric bulb is tied to the frame in such a way that it will hang above the net. This is to attract the Prawns towards the net.

The time of operation is usually the turn of the tide from low to high. Duration of a single haul may vary from 5 minutes to 1/2 hr depending on the availability of prawns. About 1 litre of kerosene is needed for a day operation.

A scoop net locally called 'Boals' is used to take out the catch from the pouch. One person will stand on the Kalasanthi or pivot pole and scoop the catch out. Best catch is obtained between February and April period. Except at barmouth region operations are suspended during monsoon seasons.

II. Free Nets

Apart from the above mentioned important fishing gears, several others falling under free net category are used for catching prawns. They are cast net, drag nets, seine nets and drift nets.

a) Cast net (Veechu Vala)

Cast net fishing goes on mainly in northern regions for penaeid prawns while in southern region it is operated to catch freshwater prawns, namely *Macrobrachium rosenbergii* and *M. idella*.

Stringed type of cast nets are used in Vembanad Lake. It is a bell shaped net weighted using lead beads along the perimeter. The

PLATE IV - CAST NET

central line branches out into several lines and sub-lines and finally connected to the border of the net which helps in heaving the net together so that the prawns will not escape.

Operator holds the net in such a way that it can be skillfully thrown out on the water to fall horizontally and enclose the prawns. The net is hauled first taking the line then the folded net is hauled inside.

From a single boat one or two persons can operate the net. The period of operation is from 5 a.m. to 2 p.m.

b) Drag net fishing:

Koruvala: It is a drag net employed to catch prawns in shallow regions of the lake. It has a square shaped mouth (90 cm depth x 4m length) and 6m long tapering bag shaped body with varying mesh sizes of 20mm, 12mm, 10mm. Two sticks are fixed at both sides of the net. The sticks keep the mouth in open condition. It is dragged by two persons and catch will get collected in the cod end. Net is operated during ebb tide during night. Operation may continue for about 4 hours. Each haul will take about 5 minutes.

c) Vadi vala: This is a trough-shaped drag net, employed to catch prawns. Net is partially doubled on itself and laced up at each end to form a pouch. The mouth is kept open by sticks placed at intervals. This type of net is generally seen in the middle and lower stretches from Arookutty down to Thanneermukkam. It is operated either singly or in groups of two through out the year in both night and day time during ebb tides.

Seine net fishing: Several kind of seine nets are operated in the backwaters with small variations.

d) Pattikanni vala is without a scare line used for catching prawns. Detailed operation and structure have been adequately described by Hornell (1937). In some places this net is called as Chemmeen vala.

e) Peru vala is a boat seine operated in southern region mainly in Kumarakam-Allapuzha. It is a small meshed net, which is payed out in concentric circles and then hauled up. Sometimes these fishermen migrate to northern regions also.

f) Drift net: (Chemmeen vala) A drift net locally called Chemmeen vala, is used to catch bigger sized *Penaeus indicus*. This can be operated during day and night. Catches are better during night. A small boat is required for operation.

III. Other methods

a) Canoe-trap fishing (Pachil Changadam or Changala Payikkal)

This method is mainly used in middle and upper stretches of the lake. This is operated in shallow regions for catching bigger sized prawns mainly *Penaeus indicus*, *Metapenaeus dobsoni*, *M. monoceros*.

PLATE V- CANOE -TRAP FISHING

This method of fishing is based on the knowledge that this prawns leap out when disturbed.

Two boats are connected together by tying bamboo poles across anterior and posterior ends in such a way that the distance between the boats is about 1 to 1.5m, and it will also keep the boats in tilted condition as shown in the photograph (Plate). A long chain is connected to boats in the front region loosely so that it will touch the ground and act as scare line. As boat moves, the chain scares the prawn and they jump out of the water and fall into the boat. Twigs are placed inside the boat to prevent their escape. Now-a days a lamp is also placed on the poles connecting the boat to attract the prawns.

b) Scoop net or Vattavala

This is a small hand net employed to catch prawns from shallow parts of the lake. It is made by bending flexible stick of bamboo pole of 2 to 3 m length and tying both ends together with a rope. A small bag net is attached to this frame. A single person operates the net by pushing and lifting at intervals through water.

c) Hand picking: This method is practiced by women during low tide. This can be done during evening or early morning hours. They keep a pot floating over the water and the collected prawns are put into it. The daily catch vary from 200 gm to 1 Kg.

PLATE VI - PADAL

d) Padal: This is a crude method for catching prawns. A three sided pouch is made by braiding coconut palm leaves and twigs. This device can be put in shallow waters. This can be taken back along with the prawns after a few hours.

SURVEY FOR ENUMERATING FIXED NETS

For planning a pilot sampling design in the beginning of the investigation, a quick survey was carried out to enumerate the stake nets and dip nets operated in the area.

A dinghy made of fibre glass fitted with 15 H.P. outboard engine was employed for 3 days. Besides the investigator, the personnel on board included the driver and a helper. Number and position of each type of net was noted down in the map available on hand. Survey was planned and conducted for 3 days covering the area between Kodungallore and Thanneermukkam. The number so enumerated formed the basis of further investigation.

DATA COLLECTION: On the basis of the number of nets operated and topography, the fishing area has been stratified into 7 strata (zones).

Since heavy concentration of nets is observed in zone 2 and zone 3, these two strata were selected for detailed investigations. From two strata 5 centres were selected proportionate to the number of operating units. Thus, one centre was selected at random from zone 2 and 4 centres from zone 3. From these selected centres, a few

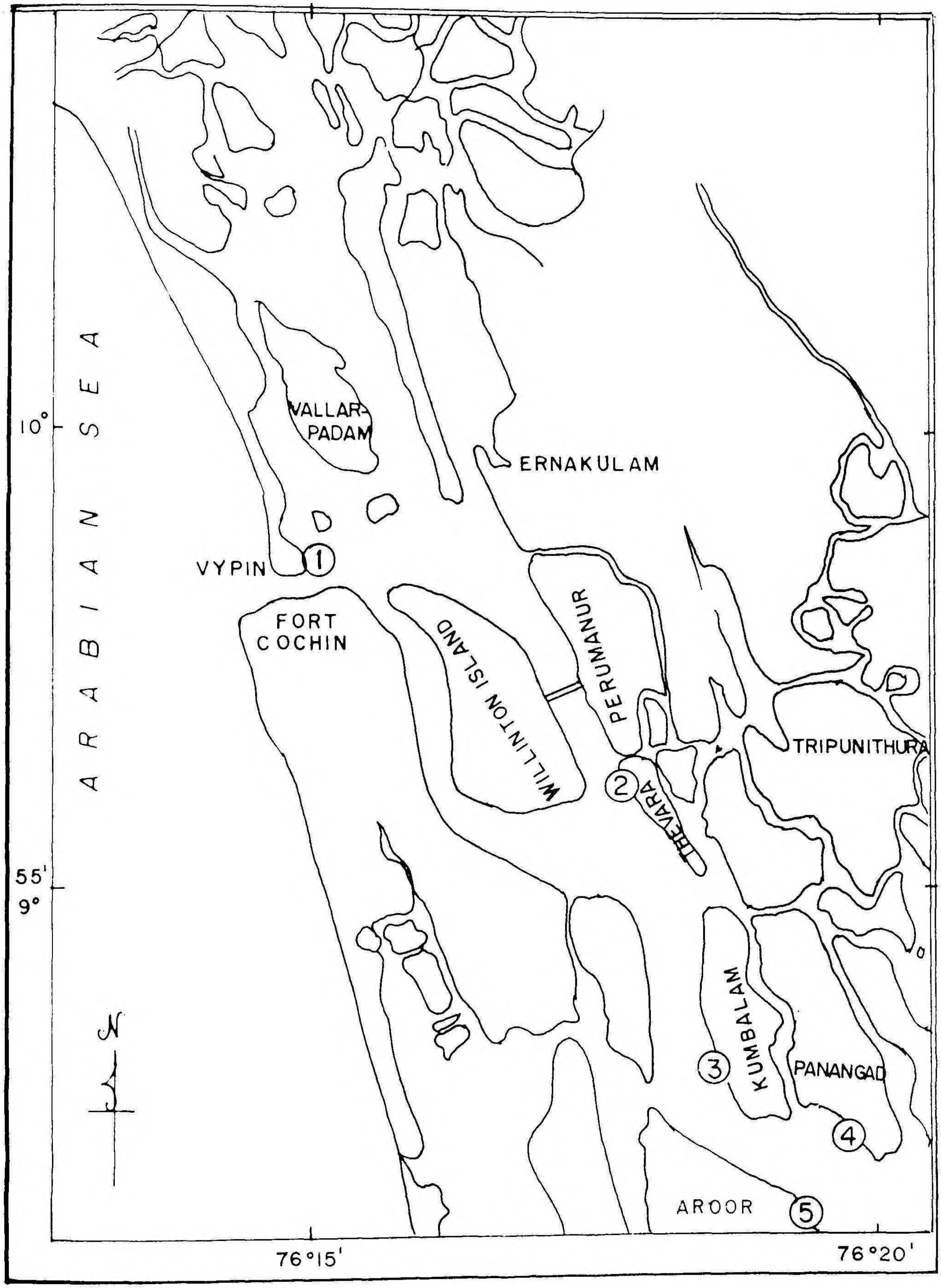

Fig. 2. Map showing sampling stations

nets were randomly selected every day for detailed investigations. The number of nets so selected varied from centre to centre, but was kept constant in a given centre. The preliminary data collection spanned for a period of three months. Data were collected as per a proforma (Appendix-I).

The data were collected on commercially important species of prawns Viz. *Penaeus indicus*, *P. monodon*, *Metapenaeus monoceros*, *M. dobsoni* and fish. The quantity of fish including prawn was accorded in respect of each net observed.

The data collection was assigned to specially selected enumerators who were given training for a period of 3 days. Quality of data was ensured by regular inspection. The fish and prawns landed used to be disposed off immediately (or in the morning) after sorting and weighing. Hence observing the weight of individual species is easily possible.

ANALYSIS

The data were subjected to detailed statistical analysis as follows. The number of nets observed at different station vary from station to station and from month to month. To facilitate comparison between stations and between months, the catch per units in respect of different species of prawns and fish was obtained by dividing the total catch by number of units operated. The resultant data were subjected to different analysis.

Before attempting sampling on any population, it is essential to have some idea about variability present in the population in respect of the target characteristics. The present study contemplates mainly estimation of the production of juvenile prawns from the Vembanad lake. The main species of prawns occurring in the lake are *Metapenaeus dobsoni*, *M. monoceros*, *Penaeus indicus*, *P. monodon*. In addition to prawns a varieties of fish also occur in the catches. These resources manifest a lot of variability over time and space. The efficiency of sampling design mainly depends upon incorporating the quantified information on the variability present. The total amount of variability present in the population is represented by the quantity S^2 as defined in section 1.

Often the value of S^2 is not known. Hence an estimate of S^2 is obtained from the sample as defined in Section 1. Also in ensuring effective representation of the population in the sample the information on variability is essential. For example it is common knowledge that to estimate any parameter which does not vary too much, we need only a few observations in the sample while if the variability is too large, we may require proportionately a large sample. Besides, the sampling theory demands a knowledge of S^2 for arriving at appropriate sample size. From the data collected S^2 was estimated for each species, each month and each station. Homogineity of the variance was tested by "Bartlett's test" as explained in section 2.

The species mentioned in the study do manifest a lot of variation from centre to centre. In order to statistically ascertain whether the catches were of same magnitude in all stations in respect of all the groups studied analysis of variance was done. Besides, the analysis of variance table provides an idea about the proportional differences in the amount of variation present between the stations and between nets within stations. Method of analysis of variance is given in the section 3.

The data on catch per net were pooled in respect of each species at each centre for each month. From the resulting data the percentage contribution of total prawns and fish were arrived at. Besides, the percentage contribution of each species to total prawn catch also was arrived at. The resultant data were subjected to analysis of variance to ascertain whether the catch per unit was uniform over time and space. The catch per unit operation arrived at as mentioned in first paragraph were subjected to statistical analysis to ascertain whether any linear trend existed in the production as we move from bar mouth to interior areas. The existance of lenear trend was ascertained statistically by linear regression analysis by the method of least squares assigning serial number 1 to 5 to the stations starting from bar mouth. Significance of the trend was tested by ' t '-test. Method is given in section 5.

On the basis of the results obtained and some practical considerations a pilot survey was planned and executed. Zone number 3 which has the maximum number of stake nets was selected for detailed investigation.

A two stage sampling scheme was adopted with row of nets as primary stage unit (P S U) and a net as secondary stage unit (S S U). 10% of PSU and within the selected PSU, 20% of the SSU were selected for detailed investigation. The data collected in pilot survey were also analysed to arrive at suitable sampling design.

DIP NET FISHERY

The dip net fishery was not active during the period of study. However the fishery resumed in September and data were collected on this fishery in September using a two stage sampling design. The entire region was divided into clusters of nets on the basis of the topography and also on the basis of distribution of dip nets as arrived at by the initial survey. In the present study only dip nets available in zone 3 were considered. However extension to the entire lake area is straightforward. In the zone concerned however for the study the entire clusters were included in the sample. Within cluster nets were selected with a sampling proportion of 10%.

METHOD OF ANALYSIS

SECTION -1

Variance Estimate:

Let a sample of n observations be drawn and observations be $X_1, X_2, X_3 \ldots X_n$ from a population of N units $X_1, X_2, X_3 \ldots X_N$ without loss of generality. Then the population Mean square Error M S E = S^2 defined as

$$S^2 = \frac{1}{(N-1)} \sum_{i=1}^{N} (Xi - \bar{X})^2$$
$$= \frac{1}{(N-1)} \left[\sum Xi^2 - \frac{(\sum Xi)^2}{N} \right]$$

Where $\bar{X}$ = the population mean given by

$$\bar{X} = \frac{X_1 + X_2 + \ldots + X_n}{N}$$
$$= \frac{1}{N} \sum_{i=1}^{N} X_i$$

without loss of generality, let $X_1, X_2, \ldots X_n$ be a sample then an estimate of S^2 is given by

$$\frac{1}{n-1} \sum (X_i - \bar{X})^2$$

Where $\bar{X} = \frac{1}{N} \sum_{i=1}^{n} X_i$, the sample mean.

Homogeneity of the variances for different classes is tested by Bartlett's - test of homogeneity of variances.

SECTION-2

BARTLETT'S -Test of homogeneity of variance

Let S_1^2 , S_2^2 ... S_a^2 be the variances estimated from a classes with n_1, n_2, n_3 .... n_a degrees of freedom. Compute the following:

$$M = \left[(\Sigma ni) \log \bar{S}^2 - \Sigma ni \log Si^2 \right]$$

Where $\bar{S}^2 = \Sigma ni Si^2 / \Sigma ni$

and $$C = 1 + \frac{1}{3(a-1)} \left[\Sigma \frac{1}{ni} - \frac{1}{\Sigma ni} \right]$$

Then Chi- Square = M/c follows chi-square distribution with (a-1) degrees of freedom.

Conclussions can be drawn by referring to Chi-square table for chosen level of confidence.

SECTION -3

Analysis of Variance

(One way classification: Unequal Observations per class)

Method: Let the data be classified into 'C' classes. Let the number of observation in different classes be n_1, n_2, n_3, ... n_c. Data lay out will be as follows:

Class Observation	1	2	3	c	Total
1	X_{11}	X_{21}	X_{31}	X_{c1}	
2	X_{12}	X_{22}	X_{32}	X_{c2}	
3	.	.	.	.	
	X_{1n1}	X_{2n2}	X_{3n3}	X_{cnc}	
	$X_{1.}$	$X_{2.}$	$X_{3.}$	$X_{c.}$	G

STEP-1

Let X_{ij} denote the j^{th} observation in the i^{th} class.

Find the sum of all observations under different classes separately.

Then let $X_1 = \sum_{j=1}^{n1} X_{1j}$

$X_2 = \sum_{j=1}^{n2} X_{2j}$

$X_i = \sum_{j=1}^{ni} X_{ij}$

STEP -2 Find the grand total $G = \sum_{j=1}^{c} \sum_{j=1}^{ni} X_{ij}$

$= \sum_{c=1}^{n} X_i$

Let $N = n1 + n2 + n3 \ldots\ldots nc = \sum_{i=1}^{c} ni$

STEP-3

Find the crude sum or squares $CRSS = \sum_{i=1}^{c} \sum_{j=1}^{ni} X_{ij}^2$

Correction factor $CF = \frac{G^2}{N}$

Corrected total sum of squares $TSS = CRSS - CF$

$= CRSS - \frac{G^2}{N}$

Sum of squares due to classes (CSS)

$= \frac{Xi^2}{n_1} + \frac{X_2^2}{n_2} + \ldots + \frac{X_c^2}{n_c} - CF$

Sum of squares due to error = TSS - CSS

set up analysis of variance table as follows:

SOURCE	DF	S.S	MSS	F
SS due to class	$C-1$	CSS	$\frac{CSS}{(C-1)}$ = MCSS	$F = \frac{MCSS}{MESS}$
SS due to error	$\sum n_1 - c$	TSS-CSS = ESS	$MESS = \frac{ESS}{\sum n_1 - c}$	
TOTAL SS	$\sum n_c - 1$	TSS		

F - value observed in compared against table value of F for (C-1) and $(\sum n_1 - c)$ degrees of freedom and conclusion are drawn.

DF = Degrees of freedom

SS = Sum of squares

MSS = Mean sum of squares

MICSS = Mean class sum of square

MESS = Mean error sum of squares

SECTION -4

Fitting Linear Trend by the Method of Least Squares

Let the stations be assigned serial number 1, 2, ..., n

let the catches obtained from station -

1,2,3,..., n be x_1, x_2, x_3 ... x_n

The data are arranged as follows

Station	Catch
1	x_1
2	x_2
3	x_3
.	.
.	.
n	x_n

The linear trend is fitted by the following regression function.

$X = a + bt$, where X is the catch and 't' is the number of station.

the slope of the line ' b ' is found out by

$$b = \frac{\sum_{i=1}^{n} xiti - \frac{\sum_{i=1}^{n} xi \sum ti}{n}}{\sum ti^2 - \frac{(\sum ti)^2}{n}}$$

SECTION -5

't' - test for slope of the regression 'b'

Compute the following

1. Deviation sum of square

$$dx^2 = \left[\sum xi^2 - \frac{(\sum xi)^2}{n} \right] - \frac{\left[\sum xiti - \frac{(\sum xi)(\sum ti)}{n} \right]^2}{\sum ti^2 - \frac{(\sum ti)^2}{n}}$$

An estimate of the population variance σ^2 is obtained as

$$\hat{\sigma}_x^2 = \frac{1}{n - 2} dx^2$$

$$V(\hat{\beta}) = V(b) = \frac{\hat{\sigma}_x^2}{\sum ti - \frac{(\sum ti)^2}{n}}$$

$$SE(b) = \sqrt{V(b)}$$

$$t_{(n-2)\ df} = \frac{b}{SE(b)}$$

Observed 't' is compared with table value of 't' for (n - 2) df at chosen level of significance.

RESULTS AND DISCUSSION

A survey was conducted to study the number and concentration of fixed nets in the lake. On the first day of survey area between Vypeen and Kodungalloor was covered. Maximum concentration of stake net was observed between Vypeen and Edavanakad and also in the eastern side of Vallarpadom island. Dip nets were sparsely distributed in this area. In the eastern side both types of nets were absent. Heavy concentration of dip nets were seen in the region between Munambam and Edavanakad, near the bar mouth region and in the tidal canal that is going to southern side near the bar mouth.

On the second day the region between Thevara and Thanneermukkom was covered. Heavy concentration of stake nets were observed in the area between Thevara and Perumbalam. Along the long stretch of narrow backwaters extending between Vayalar east and Arukutty, both types of net were found sparsely distributed.

On the 3rd day of area west of Edacochin bridge was surveyed, dip nets were observed all along the sides and a few rows of stake nets were seen at the mouth region.

Based on the survey the whole lake was divided into 7 zones and the nets present in each zone is given in the table (1).

TABLE 1: Table showing different zones, Number of nets and their percentages in each zone.

Zone No.	Description	Stake Net			Dip net	
		Total No.	%	No.of rows	Total No.	%
1	Kodungalloor to Mulavukadu	353	4.4	33	534	38.3
2	Mulavukadu to Venduruthy Bridge	1184	14.6	44	154	11.0
3	Venduruthy to Perumbalam	4021	49.6	76	283	20.3
4	Edacochin to Kumbalangi	198	2.4	9	176	12.6
5	Arookutty to Vayalar east	531	6.5	24	63	4.5
6	Perumbalam to Vaikom	1576	19.5	42	167	12.0
7	Vaikom to Thanneermukkam	240	3	5	18	1.3
Total		8103	100	233	1395	100

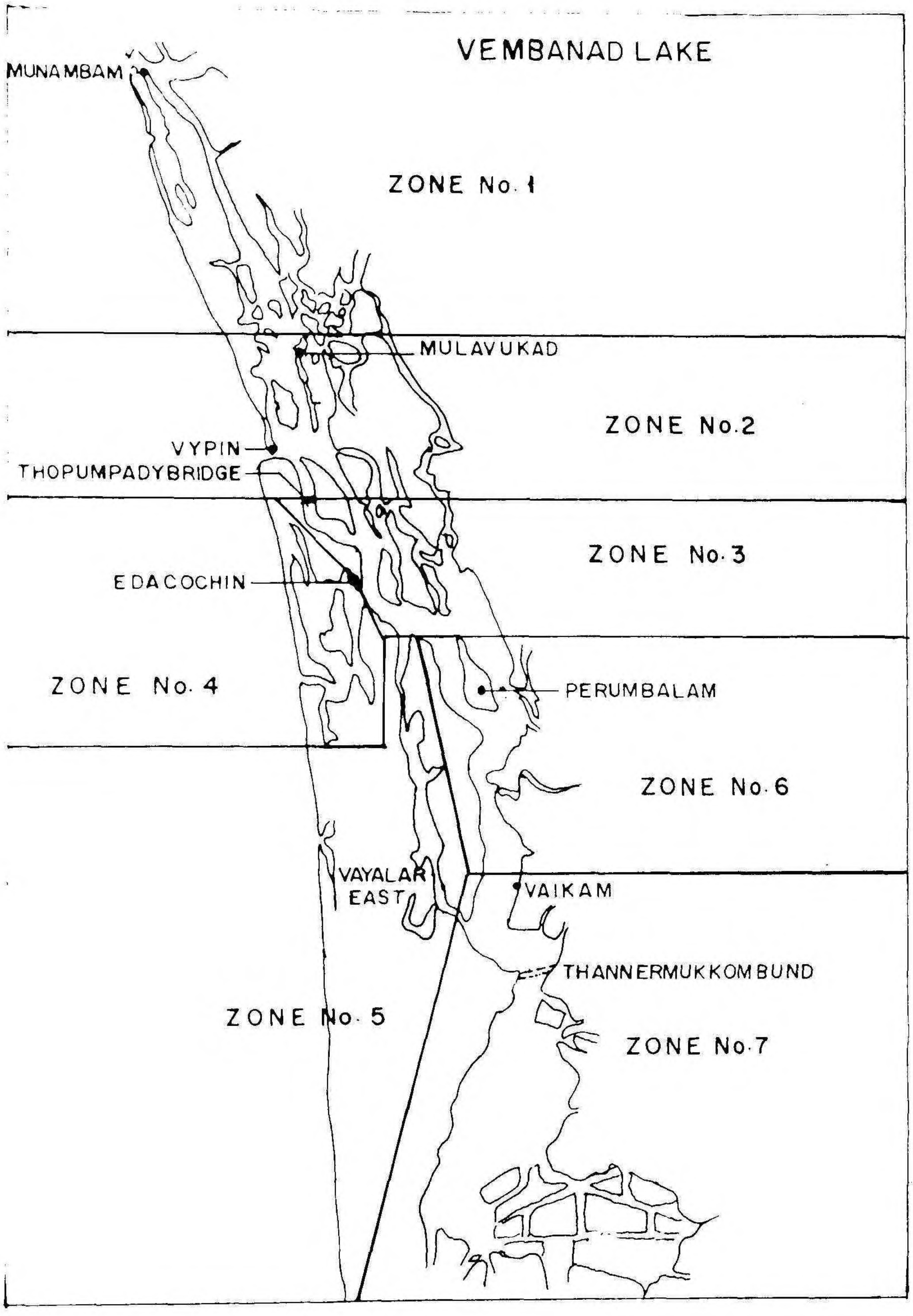

Fig. 1. Map showing different zones

It can be seen from the table that maximum number of stake net points is in the region between Venduruthy and Aroor (zone 3) followed by zone 6 (Perumbalam to Vaikom) and the least is available in the zone 7 that is Vaikom to Thanneermukkam bund. The number of nets per row also vary from zone to zone. Maximum number of nets per row is observed in zone 3 (53/row) and is followed by zone 7 (48/row). The least is observed in zone (1) - 11 nets/row. This is because northern region is comparatively narrow while the southern region in broader.

Out of total 8103 stake nets observed, zone-1 accounts for 4.4%, zone 2 - 14.6%, zone 3-49.6%, zone 4-2.4%, zone 5 -6.5%, zone 6- 19.5% and zone 7- 3%.

In general, central portion is having heavy concentration of nets except in zone 4 (Edacochin to Kumbalangi) where only 9 rows are present. This is because the area is almost closed with narrow mouth and with less tidal influence. The number per row depends on the expanse of the water body and tidal force.

It could be seen that the maximum concentration of dip nets is in the zone-1 (534) followed by zone-3 (283). The least number (18) nets is observed in zone 4.

It could be seen that while zone-1 accounts for only 4.4% of the total stake nets in the area it accounts for 38.3% of the dip nets. In zone-2 stake nets accounts for 14.6% and dip nets 11.0%. While 49.6% of the stake nets and 20.3% of dip nets are found in zone-3.

The pattern of distribution of nets in zone-4 is similar to that of zone one with 2.4% of stake nets and 12.6% of dip nets. Zone 5 accounts for 6.5% of stake nets and 4.5% of dip nets. Zone 6 and 7 account for 19.5% and 3% of stake nets respectively, while these two zones account for 12% and 12.5% of dip nets respectively.

The study started with a hypothesis that a linear trend might be discernable in the catches as we move from bar mouth to interior regions, since the effect of tides may be less felt as we progress. But the analysis on catch per operation did not reveal any trend in respect of July and August. It might be mentioned that the fishery was very poor in these two months. With commencement of active fishing in September, the trend in the fishery also has undergone conspicuous change. The data collected on Metapenaeus dobsoni in September when subjected to analysis revealed a clear decreasing trend. Needless to mention M. dobsoni remains the mainstay in the fishery throughout and constitutes nearly 80% of the total prawns and this determines the trend of over all catches.

TABLE 2: Estimated catch (Kgs) of prawns and fish in zone 2 & 3 during July to September 1990.

July	Zone-2	Zone-3
Total catch	67938	241140
Total prawns	29530	149593
Total fish	18408	91547
August		
Total catch	37622	125080
Total prawns	26045	71214
Total fish	11577	53866
September		
Total catch	151628	332298
Total prawns	135754	271015
Total fish	15874	61283

Results of preliminary survey

The data collected from 5 centres Fig.2 were statistically analysed to ascertain whether there is any difference between centres in the catches of prawns and fish. In Vypeen it was observed in the month of July, one unit of operation realized a total catch of 1.34 Kg total fish out of which 0.83 Kg. was prawns and 0.51 Kg. fish. A preliminary estimate of the total fish catch in the zone showed that the total catch in July in Vypeen zone was 67938 Kg. with a composition of 29530 Kg. prawns 18408 Kg. of fish.

In the month of August, the average catch realized at Vypeen was 1.025 Kg. which was constituted of 0.710 Kg. of prawns and 0.315 Kg. of fish. The total catch in August in this zone was estimated as 37622 Kg. which comprised 26045 Kg. of prawns and 11577 Kg. of fish.

In September the unit operation realized a total catch of 4.27 Kg. out of which prawns had a share of 3.82 Kg. complemented by 0.45 Kg. fish. The total catch for the month of September was 151628 Kg. with a composition of 135754 Kg. prawns and 15874 Kg. fish.

Unit operation in zone 3 realized a catch of 1.93 out of which the share of prawns was 1.20 Kg. complemented by 0.73 Kg. if fish. Total estimate for the month of July was 241140 Kg. composed of 149593 Kg. prawns and 91547 Kg. fish.

In August the unit operation in the zone realized a total catch of 1.00 Kg. constituted of 0.57 Kg. of prawns and 0.43 Kg. of fish. Total estimate of catch for the month of August was 125080 composed of 71214 Kg. prawns and 53866 Kg. fish.

In September unit operation realized total catch of 3.01 Kg. of fish of which 2.45 Kg. was constituted by prawns and 0.56 Kg. of fish. Total estimate of catch was 332298 constituted by 271015 of prawns and 61283 Kg. of fish.

Comparison of catches at different stations

The statistical analysis of the data by the analysis of variance explained in section 3 showed that in general there was no difference between the catch levels at different stations observed.

The result of analysis are given in Table 3 to 8

TABLE 3

Metapenaeus dobsoni

Source	DF	SS	MSS	F
Station	4	10.8195	2.7049	1.2676 NS*
Error	276	588.9615	2.1339	

TABLE 4

Metapenaeus monoceros

Source	DF	SS	MSS	F
Station	4	0.1114	0.0153	2.25 NS
Error	276	1.8997	0.0068	

TABLE 5

Penaeus indicus

Source	DF	SS	MSS	F
Station	4	0.6478	0.16195	9.170 S**
Error	276	4.8749	0.01766	

TABLE 6

Total prawn

Source	DF	SS	MSS	F
Station	4	14.8362	3.70905	1.7338 NS
Error	276	590.4191	2,1392	

TABLE 7

Fish

Source	DF	SS	MSS	F
Station	4	3.0987	.7747	9.7936 S
Error	276	21.8444	0.0791	

TABLE 8

Total catch

Source	DF	SS	MSS	F
Station	4	20.4974	5.12435	2.2103 NS
Error	276	639.8781	2.3184	

It may be noted that while there was no significant difference in respect of different species of prawns, except _P. indicus_, _P. indicus_ showed significant difference between stations. This may be due to the reason that _P. indicus_ being a stenohaline species, which might have migrated downwards towards bar mouth region.

Fish also has shown significant difference between stations due to high catch in Thevara region.

Homogeneity of variance

Homogeneity test using, Bartlett's chisquare performed on the variance estimates showed significant differences over stations and over time. The results are given in table number 9.

TABLE 9

Estimated monthwise variances of different species of prawns, fish, total prawns and total fish and values of Bartlett's chi-square.

Month	Dobsoni	Indicus	Monoceros	Monodon	Total prawn	Fish	Total	D.F.
July	0.1235	0.0231	0.0033	0.0005	0.0179	0.0529	0.3280	120
August	0.8942	0.0130	0.0065	0.0001	0.1791	0.1178	0.4122	79
Sept.	4.7758	0.0075	0.0100	0.0015	4.9400	0.6198	5.1099	78
Chi-square	415.57	28.15	29.83	48.09	593.82	143.93	222.16	

TABLE 10 Estimated stationwise variance of different species of prawns fish, total prawns and total fish and values of Bartlett's chi-square.

Species	Vypeen	Thevara	Kumbalam	Panangad	Aroor	Chi-square
Dobsoni	4.6663	1.79704	1.52525	0.7419	0.4866	85.173
Indicus	0.01394	0.01652	0.00884	0.0304	0.013	20.80684
Monoceros	0.00626	0.0035	0.00225	0.0162	0.0063	55.88132
Monodon	.000075	0.000125	0.000315	0.0011	0.000032	193.0395
Total prawn	4.7109	1.7199	1.4913	0.844	0.45897	84.756
Fish	0.08195	.0769	.0922	0.1073	.03003	18.729
Total catch	4.9739	1.9848	1.7643	0.7708	.5464	82.948
DF	76	59	45	50	45	

Trend Analysis

It is worth noting that variance in respect of *M. dobsoni* is found to follow a linear trend, over stations. This has resulted in a linear trend in the variances of total prawns and total fish catch over station. Significant trend in the variances could be observed only in respect of

M. dobsoni and as a consequence in total prawns and total fish catch (including prawns).

TABLE 11 Catch per operation (Kg) of prawns (specieswise) and fish in the five stations during the period July - September 1990.

Month	Species	Vypeen	Thevara	Kumbalam	Panangad	Aroor
July	M.dobsoni	0.469	0.9185	0.9278	0.7221	0.6877
	P.indicus	0.2044	0.2619	0.2	0.2957	0.1201
	M.monoceros	0.1487	0.1329	0.1139	0.1462	0.1063
	P. monodon	0.0042	0.0028	0.0046	0.0150	0.0017
	Fish	0.5149	0.8430	0.7542	0.644	0.6396
August	M.dobsoni	.4662	0.5588	0.3732	0.3953	0.3804
	P.indicus	0.1595	0.1759	0.0804	0.062	0.0328
	M.monoceros	0.0976	.0657	0.0321	0.0307	0.1020
	P.monodon	0.0043	0.001	0.0023	0.007	0.0064
	Fish	0.3153	0.4558	0.2479	0.6427	0.3583
Sept.	M.dobsoni	3.6057	2.7344	2.4464	1.8527	1.3996
	P. indicus	0.16	0.0715	0.025	0.108	0
	M.monoceros	0.1128	0.0578	0.0384	0.0753	0.0201
	P.monodon	0.0057	0.0102	0.0027	0.001	0.001
	Fish	0.4469	0.6977	0.45	0.4209	0.4427

Table 12 : Results of trend analysis

Month	Catagory	Intercept a	Std. dev. of intercept	Slope b	Std. dev. of slope	t
July	*M.dobsoni*	0.6727	0.2247	0.0241	6.7748-02	0.36
	P.indicus	0.2569	7.7139-02	-0.0135	2.3258-02	0.58
	M.monoceros	0.15105	1.8560-02	7.15-03	5.56601-03	1.28
	P.monodon	0.0035	6.3268-03	0.0007	1.9076-03	0.38
	Fish	0.664	0.05078	5.0400-03	4.5462-02	0.11
August	*M.dobsoni*	0.5353	0.0702	0.3335	2.1171-02	1.58
	P.indicus	0.2123	2.7957-02	0.0367	8.4294-03	4.35
	M.monoceros	0.0744	0.0411	0.0028	1.2401-02	0.23
	P.monodon	0.00114	2.4324-03	0.001	7.3339-04	1.39
	Fish	0.3221	0.1781	2.7290-02	5.3708-02	0.51
Sept.	*M.dobsoni*	3.9959	0.1546	0.5294	4.6615-02	11.36
	P.indicus	0.1580	5.5471-02	0.0284	1.6725-02	00.02
	M.monoceros	0.1113	2.8802-02	0.0168	8.6841-03	1.93
	P.monodon	0.0097	3.1084-03	0.0019	9.3723-04	1.98
	Fish	0.5572	0.1291	2.8520-02	3.8928-02	0.73
					Table value	3.18 (5% level)

The variance in respect of other species of prawns did not show any trend. However any design attempted on the basis of observations on *M.dobsoni* is likely to reflect the system adequately since the proportion of other species in the catch is too low to be reckoned with.

To study the variation in the relative abundance of various species/ fish, the percentage contributions of different species in average catch per operation was subjected to analysis of variance. The result of the analysis are presented in the table. Station wise/monthwise percentage contribution of prawn and fish in catch per unit operation and result of analysis of variance.

Total Prawns TABLE 13

Percentage contributions

MONTH	VYPEEN	THEVARA	KUMBALAM	PANANGAD	AROOR
July	61.4	61.0	62.3	64.8	58.9
August	69.6	63.8	66.3	43.5	59.4
September	89.7	80.5	84.8	82.9	76.5

TABLE 14

ANOVA TABLE

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Centres	4	86.359	21.590	1.43	N.S
Months	2	681.258	340.629	22.56	HI.SIG(1%)
Error	8	120.793	15.099		

TABLE 15

FISH

MONTH	VYPEEN	THEVARA	KUMBALAM	PANANGAD	AROOR
July	38.6	39.0	37.7	35.2	41.1
August	30.4	36.2	33.7	56.5	40.6
September	10.3	19.5	15.2	17.1	23.5

ANOVA TABLE

TABLE 16

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Stations	4	86.367	21.592	1.43	N.S.
Month	2	681.266	340.633	22.56	HI.SIG(1%)
Error	8	120.781	15.098		

Stationwise/Monthwise percentage contribution of different species of prawn in the total prawn catch and results of analysis of variance

TABLE 17

M.dobsoni

MONTH	VYPEEN	THEVARA	KUMBALAM	PANANGAD	AROOR
July	56.9	69.9	74.2	61.3	75.1
August	64.4	69.7	76.5	79.7	73.0
September	92.8	95.0	97.4	90.9	98.5

TABLE 18

ANOVA TABLE

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Centres	4	250.90	62.727	2.65	N.S.
Month	2	2125.477	1062.738	44.90	HI.SIG(1%)
Error	8	189.352	23.669		

TABLE 19

P. indicus

MONTH	VYPEEN	THEVARA	KUMBALAM	PANANGAD	AROOR
July	24.8	20	16.1	25.1	13.2
August	21.9	22.1	16.6	12.3	6.5
September	4.2	2.5	1.1	5.4	0.1

TABLE 20 ANOVA TABLE

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Centre	4	193.722	48.431	3.47	N.S.
Month	2	809.337	404.669	28.96	HI.SIG(1%)
Error	8	111.790	13.974		

TABLE 21

M. monoceros

MONTH	VYPEEN	THEVARA	KUMBALAM	PANANGAD	AROOR
July	18.0	10.0	9.3	12.5	11.6
August	13.3	8.2	6.6	6.7	19.0
September	3.0	2.2	1.5	3.7	0.1

TABLE 22 ANOVA TABLE

Source	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Centre	4	60.552	15.138	1.57	N.S
Month	2	401.800	200.900	20.90	HI.SIG(1%)
Error	8	76.909	9.614		

TABLE 23

P. *monodon*

MONTH	VYPEEN	THEVARA	KUMBALAM	PANANGAD	AROOR
July	0.4	0.2	0.5	1.2	0.2
August	0.5	0.1	0.4	1.4	1.6
September	0.1	0.4	0.1	0.1	0.1

TABLE 24

ANOVA TABLE

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Centre	4	9.564	2.391	0.82	N.S
Month	2	16.551	8.276	2.84	N.S
Error	8	23.303	2.913		

It could be observed from the table, in the case of total prawns and total fish the analysis of variance revealed that there is no significant difference between stations ($F_{4,8}$ - 1.43, P>.25). But the test established significant difference between months ($F_{2,8}$- 22.56 P<.005). This is due to seasonal variations present in the fishery particularly due to comparatively better catches in the month of September compared to the catches in July and August.

Similar trends could be observed in respect of proportions of different species of prawns. Analysis of variance on percentage contribution of *M. dobsoni* showed a F value for stations 2.65 against

4 and 8 degrees of freedom, which is non-significant $(P>.1)$ while F for months showed a significant value of 44.90 $(p<.005)$ Similar results are observed in respect of species of prawns also. Results are given in table 18 to 24.

It has been established that where the characteristic under study displays a linear trend, stratified sampling is superior to simple random sampling or systematic sampling.

$V_s = V_{sy} = V_R = V/n \quad : 1 : n$ (Sukhatme & Sukhatme- 1976)

V_s, V_{sy} & V_R respectively being variances under stratified, systematic and simple random sampling.

Besides, stratification facilitates easy execution of the survey programme in addition to leading to estimates of precision of a higher order. Stratification consists in dividing the population into sub groups according to some criteriom to facilitate increase in the precision of estimates or to facilitate ease in the administration of the survey or both. In the present study stratification has been resorted to according to the topography of the area and intensity of fishing activities. On the basis of the preliminary investigation it has been found that the following scheme of sampling will lead to reliable estimates of the characteristic under study.

The following terms are defined.

Sampling Frame Days of the month together with serial numbers of rows of nets form the frame of sample survey.

Primary Stage Unit: The row-day combination is taken as the primary stage unit.

Secondary Stage Unit: A net within the row of net.

Simple random Sampling: (random sampling for brevity)

Simple random sampling is a sampling method such that an equal probablity of selection (equal to the receprocal of the number of available units) is assigned to each available unit in the population at the first and each subsequent draw.

Stratified Sampling: Stratified random Sampling is the method of sampling by which the population is divided into a certain number say K, classes and a sample composed of K random samples one from each class.

Two stage sampling: Elements in the population are grouped into clusters: The procedure of selecting clusters and then selecting a specific number of elements from each selected cluster is known as two-stage sampling.

Sampling design followed for pilot study:

A stratified two stage design has been evolved and tested as a pilot case. As stated earlier a geographical zone stratum over space and a month a stratum over time. A zone-month therefore sorms a basic stratum for sampling purpose. A row of net is taken as the primary stage, unit and within the selected unit a specified percentage of the nets are selected as second stage units. In both the stages sampling is done by SRS without replacement.

From the selected second stage units data are collected as per the proforma (appendix)

Estimates of catch per net are obtained as follows:

In defining various quantities the notation used by Sukhatme & Sukhatme, 1976 is followed:

Let the population be divided into K Strata with N_t first stage units in the t^{th} stratum.

then $\sum_{i=1}^{K} N_t = N$, the total number of first stage units in the population.

Let the number of second stage units in the i^{th} first stage unit, belonging to the t^{th} stratum M_{ti},

Let M_{t0} be the total number of second stage unit in the t^{th} stratum so that we have

$$M_{t0} = \sum_{i=1}^{Nt} Mti$$

Let $\bar{M}_t$ = mean number of Second stage unit per stratum

then we have
$$M_{to} = N_t \bar{M}_t$$

Let n be the total number of first stage unit to be included in the sample and n_t be the number of first stage units in the sample from t^{th} stratum.

then, $$n = \sum_{i=1}^{k} n_t$$

Let m_{ti} denote the number of second stage units to be sampled from i^{th} selected first stage unit.

Besides, we have the following definitions.

$$\bar{Y}_t = \frac{1}{M_{to}} \sum_{i=1}^{N_t} \sum_{j=1}^{M_{ti}} Y_{tij}$$, the population mean per second stage unit in the t^{th} stratum.

$$\bar{Y}_{ts} = \frac{1}{\bar{M}_t n_t} \sum_{i=1}^{n_t} \frac{M_{ti}}{m_{ti}} \sum_{j=1}^{m_{ti}}$$ the sample mean per second stage units in the t^{th} stratum

$$\bar{Y} = \frac{\sum_{i=1}^{k} M_{to} \bar{Y}_t}{\sum_{i=1}^{k} M_{to}} = \sum_{i=1}^{k} w_i \bar{Y}_t$$

the population mean per second stage unit in the population.

Where $$W_i = \frac{M_{t0}}{\sum_{i=1}^{k} M_{t0}} = \frac{M_{t0}}{M_0} \qquad \text{(Say)}$$

and $\bar{Y}_w = \sum_{i=1}^{k} w_i \bar{Y}_{ts}$, , the corresponding estimate from the sample.

Now, $\bar{Y}_w$ is an unbiased estimate of $\bar{Y}$ and $\bar{Y}_{ts}$ is an unbiased estimate of $\bar{Y}_t$

Proof :

We have
$$E(\bar{Y}_{ts}) = E\left(\frac{1}{\bar{M} n_t} \sum_{i=1}^{n_t} \frac{M_{ti}}{m_{ti}} \sum_{j=1}^{m_{ti}} Y_{tij}\right)$$

$$= \left[\left(\frac{1}{\bar{M}_t n_t} \sum_{i=1}^{n_t} E\left(\frac{M_{ti}}{m_{ti}} \sum_{j=1}^{m_{ti}} Y_{tij} \middle| i\right)\right]$$

$$= \left[\frac{1}{\bar{M}_t n_t} \sum_{i=1}^{n_t} E\left(\frac{M_{ti}}{m_{ti}} \frac{m_{ti}}{M_{ti}} \sum_{j=1}^{M_{ti}} Y_{tij}\right)\right]$$

$$= \left[\frac{1}{\bar{M}_t n_t} \sum_{i=1}^{n_t} E\left(\sum_{j=1}^{M_{ti}} Y_{tij}\right)\right]$$

$$= \left[\frac{1}{\overline{M}_{nt}} \; \frac{n_t}{N_t} \sum_{i=1}^{N_t} \sum_{j=1}^{M_{ti}} Y_{tij} \right]$$

$$= \frac{1}{\overline{M}_t N_t} \sum_{i=1}^{N_t} \sum_{j=1}^{M_{ti}} Y_{tij}$$

$$= \overline{Y}_t$$

Similarly

$$E(\overline{Y}_w) = E\left(\sum_{i=1}^{k} W_i \, \overline{Y}_{ts} \right.$$

$$= E\left(\sum_{i=1}^{k} \frac{M_{t0}}{M_0} \overline{Y}_{ts} \right)$$

$$= \sum_{i=1}^{k} \frac{M_{t0}}{M_0} E\left(\overline{Y}_{ts} \right)$$

$$= \sum_{i=1}^{k} \frac{M_{t0}}{M_0} \overline{Y}_t = \overline{Y}$$

Following Sukhatme and Sukhatme, 1976.

Contd...

Following Sukhatme & Sukhatme, 1976.

$$V(\bar{Y}_w) = \sum_{i=1}^{k} wi^2 \left[\left\{ \left(\frac{1}{n_t} - \frac{1}{N_t} \right) \right\} S_{tb}^2 + \frac{1}{n_t N_t} \sum_{i=1}^{N_t} \frac{Mti^2}{\bar{M}_t^2} \left(\frac{1}{m_{ti}} - \frac{1}{M_{ti}} \right) S_{ti}^2 \right]$$

Where S_{tb}^2 is the mean square error between first stage units in the t^{th} stratum and S_{ti}^2 is mean square between second stage units in the i^{th} first stage unit in the t^{th} stratum.

An estimate of the variance

$V(\bar{Y}w)$ is given by

$$\hat{V}(\bar{Y}_w) = \sum_{i=1}^{k} wi^2 \left[\left(\frac{1}{n_t} - \frac{1}{N_t} \right) s_{tb}^2 + \frac{1}{n_t N_t} \sum_{i=1}^{n_t} \frac{Mti^2}{\bar{M}_t^2} \left(\frac{1}{m_{ti}} \, \frac{1}{M_{ti}} \right) s_{ti}^2 \right]$$

where s_{tb}^2 = Mean square error between first stage units in the t^{th} stratum in the sample and s_{ti}^2 = the mean square error between second stage units in the i^{th} first stage unit in the t^{th} stratum in the sample.

Thus, $$s_{tb}^2 = \frac{1}{n_t - 1} \sum_{i=1}^{n_t} \left(\frac{1}{\bar{M}_t} \bar{Y}_{ti.} - \bar{Y}_{ts} \right)^2$$

$$s_{ti}^2 = \frac{1}{m_{ti}} \sum_{j=1}^{m_{ti}} (Y_{tij} - Y_{ti.})^2$$

where $\bar{Y}_{ti}$ is the sample mean per second stage unit in the i^{th} first stage unit in the t^{th} stratum following the above methods the following estimates are arrived at

Stake Net Fishery

1) Mean/net operation

Total Prawns

$\hat{\bar{Y}} = \bar{Y}(w) = 2.8824$ Kg.

$\hat{SE}(\bar{Y}) = SE(\bar{Y}_w) = .4292$

Total fish

$\hat{\bar{Y}} = \bar{Y}_w = 3.0139$ Kg.

$SE(\hat{\bar{Y}}) = SE(\bar{Y}_w) = .4484$

The estimate of mean and S.E were obtained only for stratum 3 where the concentration of stake net is very heavy, extension of these results to other zones and pooling the estimate for the entire area is simple and rather straight forward. Similarly estimate of total production and the corresponding S.E also is rather straight forward.

Estimate of the total and the corresponding standard deviation are obtained by the estimates of mean by the total number of nets in the stratum.

Dip Net Fishery

Dip net fishery data collected also revealed a trend identical with that of stake net fishery. Here again the sampling procedure suggested is almost identical with that suggested for stake net fishery.

Suggested scheme of sampling: The entire dip nets in the Vembanad lake can be grouped into clusteres of unequal size depending upon the topographic conditions. Thus in the area under investigation entire dip nets are grouped into 5 clusters.

TABLE 25

Cluster No.	Description	Number of nets
1	Thoppumpady to Kumbalam	40
2	Kumbalam to Edacochin	47
3	Edacochin to Panangad	37
4	Cheppanam	50
5	South of Cheppanam	109

A two stage sampling where 1st stage units and second stage units are selected with SSRS without replacement is suggested.

The cluster of nets form the first stage unit and nets within cluster form the second stage units.

As before let N be the number of clusters in the population let M_i be the number of 2nd stage units in the i^{th} cluster ($i=1,2,\ldots,N$)

$M_0 = \sum_{i=1}^{N} M_i$ = Total number of second stage units in the population.

Let m_i be the number of second stage units to be selected from i^{th} first stage units.

$m_0 = \sum_{i=1}^{n} m_i$ = the total number of second stage unit in the sample.

Let $\bar{Y}_i = \frac{1}{M_i} \sum_{j=1}^{M_i} Y_{ij}$ = Mean per second stage unit in the i^{th} cluster.

And

$$\bar{Y} = \frac{\sum_{i=1}^{N} \sum_{j=1}^{M} Y_{ij}}{\sum_{i=1}^{N} M_i} =$$

equal to the mean of second stage units in the population.

Also we define $\bar{M} = \sum_{i=1}^{N} M_i \Big/ N$

Therefore $N\bar{M} = \sum_{i=1}^{N} M_i$

and $W_i = \frac{M_i}{\bar{M}}$

Then $\bar{Y} = \frac{1}{N} \sum_{i=1}^{N} W_i \bar{Y}_{i.}$

An estimate of $\bar{Y}$ is given by

$$\bar{Y}_s = \frac{1}{n\bar{M}} \sum_{i=1}^{n} M_i \bar{Y}_{i.}$$

Where n = total number of Ist stage units in the sample.

As before we can prove that Y_s is an unbiased estimate of $\bar{Y}$. Variance $\bar{Y}$ is given by

$$V(\bar{Y}_s) = \left(\frac{1}{n} - \frac{1}{N}\right) S_b^2 + \frac{1}{nN} \sum_{i=1}^{N} W_i^2 \left(\frac{1}{m_i} - \frac{1}{M_i}\right) S_i^2$$

where $S_b^2 = \frac{1}{N-1} \sum_{i=1}^{N} (W_i \bar{Y}_i - \bar{Y})^2$

and $S_i^2 = \frac{1}{M_i-1} \sum_{j=1}^{M_i} (Y_{ij} - \bar{Y}_i)^2$

and an estimate of variance is given by

$$V(\hat{Y}_s) = \left(\frac{1}{n} - \frac{1}{N}\right) s_b^2 + \frac{1}{nN} \sum_{i=1}^{n} \left(\frac{1}{m_i} - \frac{1}{M_i}\right) s_i^2$$

$$s_b^2 = \frac{1}{n-1} \sum_{i=1}^{n} (W_i \bar{Y}_{i.} - \bar{Y}_s)^2$$

and $$s_i^2 = \frac{1}{m_i - 1} \sum_{j=1}^{m_i} (Y_{ij} - \bar{Y}_{i.})^2$$

Following foregoing method the following results were obtained.

Total Prawns

Mean/net operation

$\hat{Y} = \bar{Y}(s) = 3.7$ Kg.

$SE(\hat{Y}) = SE(\bar{Y}_s) = 0.2938$

Total Fish

Mean/net operation

$\hat{Y} = \bar{Y}_s = 4.0143$ Kg.

$\hat{SE}(\hat{Y}) = SE(\bar{Y}_s) = 0.311$

Allocation of sample sizes

The pricision of any sampling design is given by the variance of the estimate. Now the variance of the estimate of the mean is an expression involving the mean square error in the population and the sample size. Often we may not have any information about population mean square. This would mean that to increase the precision we have to monitor the sample size usually there may be two situations.

1) Where to cost of survey is a constrained in which case we may have to design the survey in such a manner that the precision is maximum for a given cost.

2) We may have to minimise to cost for a given precision.

Let c_{1t} and c_{2t} be the costs per unit for the 1^{st} stage and second stage units in the t^{th} stratum and let C be the average total cost of the survey.

$$\text{Then } C = \sum_{i=1}^{k} C_{1t} \times n_t + \sum_{t=1}^{k} C_{2t} \frac{n_t}{N_t} \sum_{i=1}^{n_t} m_{ti}$$

Then minimising the variance subject to the condition that the total average cost is C

$$n_t = \frac{W_t \times \sqrt{\Delta t}}{\sqrt{\mu} \times \sqrt{c_{1t}}}$$

$$\text{where } \Delta t = s_b^2 - \frac{1}{N_t \bar{M}_t} \sum_{i=1}^{N_t} \frac{M_{ti}}{\bar{M}_t} s_{ti}^2$$

$$= \frac{W_t^2 \Delta t}{n^2 \times C_{1t}}$$

and $m_{ti} = \frac{M_{ti}\, s_{ti}}{\bar{M}_t} \sqrt{\frac{C_{1t}}{C_{2t\Delta t}}} \quad \begin{pmatrix} i = 1,2,\ldots,N_t \\ t = 1,2,\ldots,k \end{pmatrix}$

The analysis of variance on total fish observed reveal that variance between rows of nets is about 8 times that of variance between nets within rows. This would mean that given a sample size we should give proportionately higher representation for rows in the sample.

TABLE 25

Stake net/ Total catch

ANOVA TABLE

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Rows	35	700.925	20.026	8.09	HI.SIG(1%)
Error	211	522.150	2.475		

TABLE 26

Prawn Total

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Rows	35	667.870	19.082	8.10	HI.SIG(1%)
Error	211	497.087	2.356		

Similarly the variance between clusters in respect of dip net is observed to be about 25 times that of variance between nets within cluster. (TABLE 27) These also warrants higher representation among clusters than within cluster.

TABLE 27

Dip net/Total catch

ANOVA TABLE

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Cluster	49	2148.203	43.841	24.93	HI.SIG(1%)
Error	240	422.071	1.759		

TABLE 28

Total Prawn

ANOVA TABLE

SOURCE	D.F.	SUM.SQR	MEAN.SQR	F-VAL	REMARKS
Cluster	49	2088.542	42.623	26.08	HI.SIG(1%)
Error	240	392.170	1.634		

Even though traditionally the juvenile resources have been exploited, there has so far been no authentic assessment of the quantum of juvenile prawn exploited annually from Cochin backwaters.

There is no proper reporting on the catches by either stake nets or dip nets. There is no uniform pattern in the disposal of the catches as well. Since area concerned is quite vast and the method of operation complex and uncertain it is essential that one should think of a sampling programme to estimate the exploited resource. Perusal of the literature available would reveal that no earnest attempt has been made so far by any agency to evolve a suitable sampling design for the purpose. Hence the present investigation in this direction has is of paramount importance.

Fortunately, sampling theory has developed to such an extent that we have sampling techniques at our disposal taking into account the complexities of any nature occurring in the natural populations. Nevertheless it is essential to reconcile the practical problems and the resources at ones' disposal with the theoretical prudence. The attempt made in the present study is of utmost significance.

Since the time and resources available were very limited and meagre when compared to the vastness of the problem, only a part of the total area was considered for intense investigation. However this area contained 50% of the total stake nets in the entire Vembanad lake. Data on the catches by stake nets were collected for a period of three months July through September and on the basis of the results of the analysis of the data, intensive data collection was resorted to in October by employing the suggested sampling design. Analysis of the data collected through preliminary survey revealed no uniformity as to the levels of catch at different stations or in different months. One of the essential requirements in designing a sampling programme is the knowledge on the total amount of variation present among the population units in respect of the characteristics under study. No such information was available to start with and hence it was decided to take a few random samples, within selected station and within months. Estimates of variance arrived as proved to be varying significantly when tested for homogeneity by Bartlett's chi-square test. But it was observed that catch levels did not in general vary between stations. It may also be worth mentioning here that the period of preliminary investigation coincided with the lean period of stake net fishery in Cochin backwaters. Hence the intensity of catch did not help in choosing a proper format. Hence it was decided to take the ancillary information available, namely the number of nets. On the basis of these numbers and on practical consideration of topography, the entire area was stratified into 7 zones. Within the stratum a two stage sampling is suggested where SRS is followed in both the stages. Conventionally one would go for an estimate of the population mean $(\bar{Y})$ based on the sample mean . But since the second stage units within first stage units are not equal this would always results in a biased estimate, even though the computation is straightforward and simple. But the estimate suggested in the present study is one on the basis of the sample totals. Even though the computation is tedious and theory a little puzzling, it was felt desirable to go for an estimate that is unbiased and that which admits an estimates of variance. The same design has been suggested for both stake nets and dip nets with a little difference in the definition of first stage units. Both the estimates are found to be reasonable and agree with the reports available and admit low standard errors. However a comparison of this method with SRS revealed that the efficiency is very low. But this may due to poor sampling coverage as the pilot study stage. With improved sampling coverage as suggested in the text this efficiency is likely to improve. However, the risk is allowable as a SRS Scheme in such a complex and vast area would entail a lot of manpower and other resources.

Free nets

Besides stake nets and dip nets, a large number of free nets (described in section No.II& III, page No. 15 - 19) are also operated in the backwaters. Present investigation did not cover these nets due to paucity of time and resources. However it is suggested that the multistage random sampling design followed by CMFRI for estimating the marine fish landings can be fruitfully employed for estimating the catches by these nets.

SUMMARY

Vembanad lake which extends from Cranganore in the north to Alleppey in the south is well known to be an important nursery ground for the commercially important species of marine prawns *Viz*. *Metapenaeus dobsoni*, *M. monoceros*, *Penaeus indicus* and *P. monodon*. These species of prawns spend their juvenile stages in the backwaters and on reaching pre-adult stage gradually move on to oceanic regions. Traditionally these juvenile resources have been exploited inflicting juvenile mortality on these resources which otherwise would have supported a prominent marine prawn fishery in the country. Planning the conservation strategies in respect of these species would needless to say, require quantified information on this aspect of the problem. At present there is no authentic information on the annual quantum of catches of these juveniles from this area. No attempt has been so far known to be made to systematically collect and collate information on the catches of these juveniles. No agency is known to have made any study to evolve a suitable and scientific method collection of relevant data in this respect. Hence a study was undertaken to evolve a scientific method of collection of data on the catches of juvenile prawns from Vembanad lake area.

The foregoing chapters deal with various aspects of the study such as data collection, methods of analysis and suggestions towards a suitable sampling design.

Before starting collection of data on the resources, preliminary survey was conducted for enumerating the total number of fixed nets in the area. In course of a period of three days, the regionwise distribution of the fixed nets Viz. stake nets and dip nets were ascertained by counting the actual net points. On the basis of the distribution of nets and practical consideration of the topography, the entire Vembanad lake area has been divided into 7 strata/zones.

Zone	1	Kodungalloor to Mulavukadu
Zone	2	Mulavukadu to Venduruthy Bridge
Zone	3	Venduruthy to Perumbalam
Zone	4	Edacochin to Kumbalangi
Zone	5	Arookutty to Vayalar east
Zone	6	Perumbalam to Vaikom
Zone	7	Vaikom to Thanneermukkam

Since the resources and time available were very much limited, only the central portion of the area was considered for detailed investigation. 5 centres, 4 representing zone 3 and one representing zone 2 were selected and data on catches by stake nets were collected for a period of three months from July through September 1990. Number of centres in each zone was proportionate to the number of nets available in these zones.

The data on catches by stake nets were collected from each centre from a few nets. The number of nets varied from centre to centre but was kept constant within a centre. Data were subjected to statistical analysis in order to ascertain various features. The homogeneity of variance was ascertained by employing Bartlett's chi-square. Analysis revealed that the variances within stations and within months were all not homogeneous. Analysis of variance was employed to ascertain whether the catches were of uniform level over time and space. The analysis was performed on data on catch/unit operation. It revealed that there was no significant difference in the levels of various species of prawns except *Penaeus indicus* and in the catch of fish.

In order to ascertain whether the proportion of fish and prawn in the total catch were uniform over time and space, analysis of variance was employed on the percentage compositions of prawns and fish in the total catch and on the percentage composition of different species of prawn in the total prawns. The analysis was performed by transferring the data on arc-sin values on the squareroot of proportions. The results indicated that there was no difference in proportion over time and space.

As a linear trend can reasonably be expected in the catches as we proceed from bar mouth to interior regions, catch realized per unit operation of different species was subjected to ordinary regression analysis. It was found that in the month of September *Metapenaeus dobsoni* exhibited a clear linear trend. Since *M. dobsoni* forms major proportion in the total catch, the trends of total prawn catch and total catch are determined by trends in dobsoni catch. In earlier months (July and August) no trend was discernible. It might be mentioned here that July and August were comparatively lean periods for stake net fishery. Hence the trend shown by the fishery in the month of September were utilized for further analysis.

On the basis of the above observations a two stage stratified sampling design was thought off and implemented in the month of October. Stratification was done as indicated below. A two stage sampling within stratum was followed with a day-row (row of net) combination as the primary stage unit and within the row, net as the secondary stage unit . A zone-month formed the stratum over time and space. Since the facilities were limited as compared to the vastness of the problem, This phase of the study was confined to zone-3 where maximum concentration of stake nets is available. Every day selected for observation, 10% of the primary stage units and 20% of second stage units were selected for observations.

At both stages SRSWOR was followed. Since the data reveal a linear trend the stratification will lead to estimates with comparatively higher precision.

An estimate of the catch/ net is recommended on the basis of the sample totals.

It is also proved that the given estimate is an unbiased estimate of population mean. The variance also is estimated.

In respect of dip net fishery, a two stage sampling design is followed. The primary stage unit is cluster of nets and second stage unit ; nets within the clusters. It is found that it is easy to arrange the dip nets operated in the lake area into distinct clusters. However since the resource are limited detailed investigations are done only in zone-3. Extension of results to entire Vembanad lake area is straightforward.

The method of allocating sample size of primary stage units and second stage units also is outlined.

Following results were obtained.

TABLE Estimated catch per net and total catch in Zone-3 together with standard errors.

	Prawn	Total catch
Stake net fishery:		
Estimates of Mean catch /net	2.8824 Kg.	3.0139 Kg.
Standard Error	0.4484	0.42923
Total catch*	347703.912 Kg.	363566.76 Kg.
Standard Error	54090.492	51778.02
Dip net fishery:		
Estimates of Mean catch/net	3.732	4.0143
Standard Error	0.2938	0.311
Total catch	31684.7 Kg.	34081.4 Kg.
Standard Error	2494.36	2640.39

* for one month

In the present investigation free nets were not covered due to paucity of time and resources. However it is suggested that the multistage random sampling design followed by C.M.F.R.I. for estimating the marine fish landings can be fruitfully employed for estimating the catches by these nets.

APPENDIX-I

Proforma for recording data

Name of Zone: ....

Name of Centre:................

Name of net:...................

Date:...............

Total number of nets:...........

No. of nets observed:...........

Sl. No.	Time of setting	Time of hauling	Weight (Kg.)					
			M.dobsoni	M.monoceros	P.monodon	P.indicus	Fish	Total

Name:

Signature:

APPENDIX-II

CALCULATION OF CATCH PER NET

a) Stake net

Sl.No.	M_{ti}	m_{ti}	M_{ti}/m_{ti}	$\sum_{j=1}^{m_{ti}} Y_{tij}$ Prawn	$\sum_{j=1}^{m_{ti}} Y_{tij}$ Total catch	$M_{ti}/m_{ti} \times \sum_{j=1}^{m_{ti}} Y_{tij}$ Prawn	$M_{ti}/m_{ti} \times \sum_{j=1}^{m_{ti}} Y_{tij}$ Total catch
1	2	3	4	5	6	7	8
1	15	3	5	21.8	22.55	109.00	112.75
2	11	2	5.5	11.35	11.80	62.43	64.905
3	23	5	4.6	36.2	37.8	166.52	173.88
4	16	3	5.33	19.90	11.26	58.13	60.0
5	97	19	5.1053	103.06	110.459	526.15	563.93
6	37	7	5.105	30.938	32.697	157.94	166.92
7	8	2	4	7.19	7.69	28.76	30.76
8	24	5	4.8	29.65	31	142.32	148.8
9	63	13	4.846	69.3	72.44	334.53	351.066
10	20	4	5	27.5	28.6	137.5	143.0
11	17	3	5.666	15.95	16.77	90.38	94.92
12	15	3	5	13.3	14	66.5	70.0
13	37	7	5.285	32.91	34.564	173.95	182.674
14	103	21	4.9047	111.23	115.28	545.556	565.42
15	47	9	5.222	60.312	108.28	314.95	523.83
16	63	13	4.846	84.59	87.09	409.94	422.05
17	20	4	5	30.47	29.22	152.35	146.1
18	17	3	5.666	21.85	22.55	123.82	127.79
19	15	3	5	6.73	7.33	33.65	36.65
20.	94	19	4.947	92.1265	95.68	455.75	473.31
21	24	5	4.8	30.85	31.9	148.08	153.12
22	17	3	5.666	24.25	24.80	137.41	140.53
23	15	3	5	27.482	23.45	114.41	117.25
24	46	9	5.111	59.2133	61.101	302.58	312.288
25	64	13	4.923	79.60	81.90	391.876	403.2

Contd.....

1	2	3	4	5	6	7	8
26	36	7	5.143	28.15	5.37	144.77	151.2
27	24	5	4.8	17.65	18.65	84.72	89.52
28	11	2	5.5	8.6	9	47.3	49.5
29	73	15	4.866	0	0	0.00	0
30	8	2	4	7.60	9.8	37.0	39.2
31	109	22	4.9545	0	0	0.00	0
32	13	2	6	9.25	9.6	55.5	57.6
33	20	4	5	16.2	17.1	81.0	85.5
34	46	9	5.11	16.83	18.43	86.02	94.1978
35	36	7	5.14	0	0	0.00	0.00
36	35	7	5	14.9	15.75	74.5	78.75
37	79	17	4.647	38.92	41.115	180.84	191.0638
38	73	15	4.866	0	0	0.00	0
39	20	4	5	8.55	9.15	42.75	45.75
40	34	7	4.86	17.269	18.469	83.93	89.76
Total						6099.252	6377.1846

$\underline{\Sigma M_{ti}/m_{ti}\cdot \sum_{j=1}^{m_{ti}} Y_{tij}}$

For prawn = 6099.252

For total catch= 6377.1846

$$\bar{Y}_{ts}\ (\text{Prawn}) = \frac{6099.252}{n_t\,\bar{M}_t} = \frac{6099.252}{40 \times 52.9} = 2.88824$$

$$\bar{Y}_{ts}\ (\text{Total catch}) = \frac{6377.1846}{40 \times 52.9} = 3.0139.$$

Calculation of the estimate of variance of $\bar{Y}_{ts}$

Calculation of between sum of squares

Sl.No.	$M_{ti}/\bar{M}_t$	$\bar{Y}_{ti.}$		$M_{ti}/\bar{M}_t \times \bar{Y}_{ti.}$		$(M_{ti}/\bar{M}_t \times \bar{Y}_{ti.} - \bar{Y}_{ts})^2$	
		Prawn	Total fish	Prawn	Total catch	Prawn	Total catch
1	2	3	4	5	6	7	8
1	0.2835	7.2667	7.5167	2.0601	2.1309	0.6762	0.7796
2	0.2079	5.675	5.9	1.1798	1.2266	2.8988	3.1944
3	0.4347	7.24	7.56	3.1472	3.2863	0.0701	0.0742
4	0.3024	3.6333	3.75	1.0987	1.1340	3.1816	3.5340
5	1.8834	5.4242	5.8137	9.9447	10.6588	49.8761	58.444
6	0.6693	4.2686	4.5114	2.9850	3.1548	0.0105	0.01985
7	0.1512	3.595	3.845	0.5436	0.5813	5.4700	5.9175
8	0.4536	5.93	6.2	2.6898	2.8123	0.0371	0.0406
9	1.1907	5.31	5.57	6.3226	6.6321	11.8350	13.0913
10	0.3780	6.875	7.15	2.5987	2.7027	0.0805	0.0968
11	0.3213	5.3167	5.5833	1.7083	1.7939	1.3785	1.4884
12	0.2835	4.433	4.6667	1.2568	1.3230	2.6426	2.8591
13	0.6993	4.7014	4.9157	3.2877	3.4375	0.1643	0.1794
14	1.9468	5.2967	5.4810	10.3116	10.6704	55.1930	58.6219
15	0.8883	6.7011	6.89	5.9526	6.1203	9.4261	9.6497
16	1.1907	6.5069	6.6992	7.7478	7.9767	23.6721	24.6293
17	0.3780	7.6175	8.305	2.8794	3.1392	0.000009	0.0157
18	0.3213	7.2833	7.5167	2.3401	2.4151	0.2941	0.3586
19	0.2835	2.2433	2.4433	0.6360	0.6926	5.0463	5.3884
20	1.7767	4.8484	5.0353	8.6142	8.9462	32.8535	35.1922
21	0.4536	6.17	6.38	2.7987	2.8939	0.0070	0.0144
22	0.3213	8.0833	8.2667	2.5972	2.6560	0.0813	0.1281
23	0.2835	7.6	7.8167	2.1546	2.2160	0.5297	0.6366
24	0.8694	6.5777	6.7889	5.7187	5.9022	8.0446	8.3423
25	1.2096	6.1211	6.3	7.4041	7.62104	20.4458	21.2198

Contd.......

1	2	3	4	5	6	7	8
26	0.6804	4.0214	4.0214	2.7362	2.7361	0.0214	0.0772
27	0.4536	3.53	3.53	1.6012	1.6012	1.6415	1.9957
28	0.2079	4.3	4.3	0.8940	0.8939	3.9537	4.4944
29	1.3798	0.00	0	0.00	0.00	8.3082	9.0836
30	0.1512	4.62	4.62	0.6985	0.6985	4.7649	5.3611
31	2.0602	0.00	0	0.00	0	8.3082	9.0836
32	0.2268	4.625	4.625	1.0489	1.2025	3.3615	3.2812
33	0.3780	4.05	4.05	1.5309	1.5309	1.8266	2.1993
34	0.8694	1.87	1.87	1.6258	1.6257	1.5790	1.9271
35	0.6804	0.00	0	0.00	0.00	8.3082	9.0836
36	0.6615	2.1286	2.1286	1.4081	1.4080	2.1736	2.5789
37	1.4932	2.2891	2.2891	3.4181	3.4180	0.2870	0.1633
38	1.3798	0	0	0.0	0	8.3082	9.0836
39	0.3780	2.1375	2.1375	0.8080	0.8079	4.3031	4.8664
40	0.6426	2.4686	2.4686	1.5863	1.5863	1.6799	2.0380
Total						292.444	319.2336

$$s_{tb}^2(\text{Prawn}) = \frac{1}{n_t - 1} \times 292.444 = \frac{1}{39} \times 292.446 = 7.4986$$

$$s_{tb}^2(\text{Total catch}) = \frac{1}{n_t - 1} \times 319.336 = \frac{1}{39} \times 319.2336 = 8.1855$$

$$\left(\frac{1}{n_t} - \frac{1}{N_t}\right) s_{tb}^2$$

For total prawn $= \left(\frac{1}{40} - \frac{1}{76 \times 30}\right) \times 7.4986 = 0.1841752$

For total catch $= \left(\frac{1}{40} - \frac{1}{76 \times 30}\right) \times 8.1855 = 0.201047$

APPENDIX-IV

Calculation-within sum of squares

Sl.No.	$(M_{ti}/\bar{M}_t)^2$	$(1/m_{ti}-1/M_{ti})$	s_{ti}^2		$(1/m_{ti} - 1/M_{ti})(M_{ti}/\bar{\bar{M}}_t)^2 s_{ti}^2$	
			Prawn	Total catch	Prawn	Total catch
1	2	3	4	5	6	7
1	0.0804	0.2666	7.6259	7.5308	1.16235	0.1614
2	0.0432	0.4091	1.0512	1.125	0.0186	0.0199
3	0.1891	0.1565	0.9592	0.8943	0.0284	0.0265
4	0.0915	0.2708	0.1318	0.1225	0.0032	0.003
5	3.3613	0.0423	2.9543	3.3597	0.4204	0.477
6	0.4891	0.1158	1.7263	1.6809	0.0978	0.0952
7	0.0258	0.375	0.2520	0.2521	0.0024	0.0024
8	0.2058	0.1583	3.2721	3.325	0.1066	0.1083
9	1.4179	0.0611	2.5176	2.6391	0.2181	0.2286
10	0.1429	0.2	0.5041	0.6	0.144	0.0171
11	0.1032	0.2745	1.7559	1.7358	0.0497	0.0492
12	0.0803	0.2666	0.9308	0.9158	0.0199	0.0196
13	0.4891	0.1158	1.0750	0.9886	0.0609	0.056
14	3.7900	0.0379	5.5606	5.6886	0.7987	0.7987
15	0.7891	0.0898	0.4951	1.0137	0.0674	0.0718
16	1.4179	0.0611	2.6739	2.7743	0.2313	0.2316
17	0.1429	0.2	0.2508	0.2298	0.0072	0.0066
18	0.1032	0.2745	0.2008	0.2158	0.0057	0.0061
19	0.0804	0.2666	1.4962	1.6096	0.0321	0.0345
20	3.1566	0.0420	5.6139	5.8726	0.7443	0.7786
21	0.2058	0.1583	0.8117	0.8158	0.0266	0.0366
22	0.1032	0.2745	0.2008	0.2158	0.0057	0.0061
23	0.0804	0.2667	0.07	0.0858	0.0015	0.0018
24	0.7559	0.0894	1.3551	1.4636	0.0916	0.0989
25	1.4633	0.0613	1.8653	1.9713	0.1673	0.1768

Contd.......

1	2	3	4	5	6	7
26	0.4630	0.1151	1.939	2.0892	0.1033	0.1113
27	0.2058	0.1582	1.287	1.4083	0.0419	0.0458
28	0.0432	0.4091	1.28	1.280	0.0226	0.0226
29	1.9037	0.0530	0	0.00	0.00	0
30	0.0293	0.375	0.6613	0.72	0.0657	0.0069
31	4.2444	0.0363	0	0.00	0.00	0.00
32	0.0514	0.4167	2.0113	2.205	1.9307	0.0472
33	0.1429	0.2	0.7217	0.8092	0.1168	0.0231
34	0.7559	0.0894	0.6517	0.6889	0.044	0.0467
35	0.4630	0.1151	0.00	0.00	0.00	0.00
36	0.4376	0.1143	1.045	1.04	0.0521	0.0570
37	2.2259	0.0462	1.3285	1.3874	0.1368	0.1429
38	1.9037	0.0530	0.00	0.00	0.00	0.00
39	0.1429	0.20	0.5090	0.5473	0.0145	0.0156
40	0.4130	0.1134	1.0056	1.0247	0.0471	0.0479
Total					5.9556	4.0759

<u>Calculation within sum of squares</u>

$$\sum_{i=1}^{n_t}(M_{ti}/\bar{M}_t)^2\left(\frac{1}{m_{ti}}-\frac{1}{M_{ti}}\right)s_{ti}^2 =$$

For total prawn $= 5.9556$

For total catch $= 4.0759$

$$\frac{1}{m_t N_t} \sum_{i=1}^{n_t}(M_{ti}/\bar{M}_t)^2\left(\frac{1}{m_{ti}}-\frac{1}{M_{ti}}\right)s_{ti}^2$$

For total prawn $= \frac{5.956}{40\times76\times30} = 0.000065307$

For total catch $= \frac{4.0759}{40\times76\times30} = 0.00004469$

Calculation of standard error

$$V(\bar{Y}_{ts}) = \left(\frac{1}{n_t} - \frac{1}{N_t}\right) s_{tb}^2 + \frac{1}{m_t N_t} \sum (M_{ti}/\bar{M}_t)^2 \left(\frac{1}{m_{ti}} - \frac{1}{M_{ti}}\right) s_{ti}^2$$

For Total prawn $V(\bar{Y}_{ts}) = 0.1841752 + 0.000065307 = 0.1842405$

$$SE(\bar{Y}_{ts}) = \sqrt{V(\bar{Y}_{ts})} = \sqrt{0.1842405} = 0.42923.$$

For total fish $= V(\bar{Y}_{ts}) = 0.201047 + 0.0004469 = 0.2010916$

$$SE(\bar{Y}_{ts}) = \sqrt{V(\bar{Y}_{ts})} = \sqrt{0.201096} = 0.4484.$$

APPENDIX-V

Calculation of catch per net

b) Dip net

Sl.No.	M_i	m_i	M_i/m_i	$\sum_{j=1}^{m_i} Y_{ij}$		$M_i/m_i \times \sum_{j=1}^{m_i} Y_{ij}$	
				Prawn	Total catch	Prawn	Total catch
1	2	3	4	5	6	7	8
1	40	4	10	9.12	10.02	91.2	100.2
2	47	5	9.4	36.95	38.75	347.33	364.25
3	37	4	9.25	17.65	22.95	163.2625	212.2875
4	50	5	10	17.73	19.23	177.3	192.3
5	109	11	9.9091	31.45	34.85	371.6409	345.3318
6	40	4	10	56.08	57.63	560.8	576.3
7	47	5	9.4	68.15	69.5	640.61	653.3
8	37	4	9.25	30.77	31.97	284.6225	295.7225
9	50	5	10	16.48	18.00	164.8	180
10	109	11	9.9091	30.59	34.09	303.1191	337.8009
11	40	4	10	30.8	32.45	308	324.5
12	47	5	9.4	23.4	25.05	290.96	235.47
13	37	4	9.25	12.68	13.83	117.29	127.9275
14	50	5	10	17.5	18.67	175	186.4
15	109	11	9.9091	56.19	59.79	556.7918	592.4645
16	40	4	10	50.05	51.3	500.5	513
17	47	5	9.4	54.13	55.73	508.822	523.866
18	37	4	9.25	25.55	26.85	236.3375	248.3625
19	50	5	10	29.6	32.55	296	325.5
20	109	11	9.901	38.45	41.4	381.0045	410.2364
21	40	4	10	8.97	9.97	89.7	99.7
22	47	5	9.4	14.1	15.25	132.54	143.54
23	37	4	9.25	13.7	14.7	126.725	135.975
24	50	5	10	9.63	10.23	96.3	102.3
25	109	11	9.901	25.65	27.37	254.1682	271.0136

Contd......

1	2	3	4	5	6	7	8
26	40	4	10	9.95	10.9	99.5	101.0
27	47	5	9.5	17.08	18.73	160.552	176.062
28	37	4	9.25	12.9	13.85	119.325	128.1125
29	50	5	10	10.12	10.87	101.2	108.7
30	109	11	9.9091	22.25	24.55	220.4773	243.2682
31	40	4	10	14.2	15.35	142	153.5
32	47	5	9.4	14.93	16.33	140.342	153.502
33	37	4	9.25	11.57	10.07	107.0225	93.1475
34	50	5	10	14.8	15.9	154	159
35	109	11	9.9091	27.65	29.75	273.9864	294.7955
36	40	4	10	8.45	9.25	84.5	92.5
37	47	5	9.4	14.27	16.07	134.138	151.058
38	37	4	9.25	7.5	12.7	69.375	117.475
39	50	5	10	14.13	15.68	141.3	156.8
40	109	11	9.9091	27.85	29.75	275.9682	294.7955
41	40	4	10	10.55	14.55	125.5	145.5
42	47	5	9.4	14.15	15.05	133.01	141.47
43	37	4	9.25	13.28	14.43	122.84	133.4775
44	50	5	10	12.35	13.5	123.5	135.0
45	109	11	9.9091	26.73	29.05	264.87	195.7864
46	40	4	10	9.59	10.34	95.9	103.4
47	47	5	9.4	5.49	6.29	51.606	59.126
48	37	4	9.25	9.73	10.63	90.0025	98.3275
49	50	5	10	6.05	6.45	60.5	64.5
50	109	11	9.9091	23.87	26.5	236.53	262.5909
Total						10561.76886	11360.44864

$$\sum M_i/m_i \times \sum_{j=1}^{m_i} Y_{ij}$$

For prawns = 10561.76886   For Total catch = 11360.44864

$$\bar{Y}_s \text{ (Prawn)} = \frac{10561.76886}{m.\ \bar{M}} = \frac{10561.76886}{50 \times 56.6} = 3.732 \text{ Kg.}$$

$$\bar{Y}_s \text{ (Total catch)} = \frac{11360.44864}{50 \times 56.6} = 4.0143.$$

Calculation of estimate of variance of $\bar{Y}_s$

Calculation of between sum of squares

Sl.No.	$M_i/\bar{M}$	$\bar{\bar{Y}}_i$ Prawn	$\bar{\bar{Y}}_i$ Total catch	$M_i/\bar{M} \times \bar{\bar{Y}}_i$ Prawn	$M_i/\bar{M} \times \bar{\bar{Y}}_i$ Total catch	$(M_i/\bar{M} \times \bar{Y}_i - \bar{Y}_s)^2$ Prawn	$(M_i/\bar{M} \times \bar{Y}_i - \bar{Y}_s)^2$ Total catch
1	2	3	4	5	6	7	8
1	0.7067	2.28	2.505	1.6113	1.7703	4.4974	5.0355
2	0.8304	7.39	7.75	6.1367	6.4356	5.7826	5.8627
3	0.6537	4.425	4.59	2.8845	3.0005	0.7183	1.0271
4	0.8834	3.546	3.846	3.1325	3.3976	0.3594	0.3803
5	1.9258	2.8591	3.6182	5.5061	6.9679	3.1474	8.7238
6	0.7065	14.02	14.4075	9.9079	10.1878	38.1474	38.1121
7	0.8304	13.63	13.9	11.3184	11.5426	57.5535	56.6753
8	0.6537	7.692	7.9925	5.0286	5.2247	1.6812	1.4651
9	0.8834	3.296	3.6	2.9117	3.1802	13.9278	0.6957
10	1.9258	2.7809	3.0911	5.3555	5.9682	2.6358	3.8181
11	0.7067	7.7	8.1125	5.4416	5.7331	2.9227	2.9543
12	0.8304	4.68	5.01	3.8863	4.1603	0.0238	0.0213
13	0.6537	3.17	3.4575	2.0722	2.2602	2.7549	3.0769
14	0.8834	3.5	3.728	3.0919	3.2933	0.4097	0.5198
15	1.9258	5.1082	5.4355	9.8374	10.4677	37.2789	41.6464
16	0.7067	12.5125	12.825	8.8426	9.0434	5.1106	25.4934
17	0.8304	10.826	11.146	8.9899	9.2556	27.6455	27.4712
18	0.6537	6.3875	6.7125	4.1755	4.3879	2.7765	0.1396
19	0.8844	5.92	6.51	5.2297	5.7509	2.2431	3.0158
20	1.9258	3.6955	3.7636	6.7316	7.2471	8.9976	10.4562
21	0.7067	2.2425	2.4925	1.5848	1.7614	4.6715	5.0756
22	0.8305	2.82	3.05	2.3417	2.5327	1.9329	2.1363
23	0.6537	3.425	3.675	2.2389	2.4023	2.2293	2.5985
24	0.8834	1.926	2.046	1.7014	1.8074	4.1233	4.8704
25	1.9258	2.3318	2.4864	4.4906	4.7883	0.5757	0.5991

Contd......

1	2	3	4	5	6	7	8
26	0.7067	2.4875	2.725	1.7579	1.9258	3.7971	4.3618
27	0.8304	3.416	3.746	2.8366	3.1107	0.8017	0.8165
28	0.6537	5.225	3.4625	2.1082	2.2634	2.6367	3.0657
29	0.8834	2.024	2.174	1.7880	1.9205	3.7791	4.3840
30	1.9258	2.0227	2.2318	3.8953	4.2980	0.0267	0.0804
31	0.7067	3.55	3.8375	2.5088	2.7120	1.4962	1.6940
32	0.8304	2.986	3.266	2.4796	2.7121	1.5685	1.6957
33	0.6537	2.8925	2.5175	1.8908	1.6457	3.390	5.6103
34	0.8843	2.88	3.18	2.5442	2.8090	1.4109	1.4523
35	1.9258	2.5136	2.7045	4.8407	5.2083	1.2292	1.4256
36	0.7067	2.1125	2.3125	1.4929	1.6342	5.0136	5.6649
37	0.8304	2.854	3.214	2.3610	2.6689	1.8796	1.8101
38	0.6537	2.875	3.175	1.8794	2.755	3.4321	3.7589
39	0.8835	2.826	3.136	2.4965	0.7804	1.1527	10.4581
40	1.9258	2.5318	2.7045	4.8757	5.2083	1.3080	1.4256
41	0.7056	3.1375	3.6375	2.2173	2.5707	2.2943	2.0843
42	0.8304	2.83	3.01	1.9515	2.4995	3.1489	2.2946
43	0.6537	3.32	3.6075	2.1707	2.3582	2.4389	2.7427
44	0.8834	2.47	2.7	2.1820	2.3852	2.4025	2.6540
45	1.9258	2.43	2.7136	4.6797	5.2259	0.8981	1.4680
46	0.7067	2.3975	2.585	1.6943	1.8268	4.1522	4.7882
47	0.8304	1.098	1.258	0.9118	1.0446	7.9530	8.8191
48	0.6537	2.4325	2.6575	1.5901	1.7372	4.5877	5.1852
49	0.8834	1.21	1.29	1.0639	1.1396	7.0421	8.2639
50	1.9255	2.17	2.48	4.1790	4.7760	0.1998	0.5802
Total						300.1539	338.45

Contd......

Calculation of between sum of squares

$$(M_i / \bar{M} \times \bar{Y}_i - \bar{Y}_s)^2 =$$

For prawns $= 300.1539$

For Total catch $= 338.45$

$$s_{tb}^2 \text{ (Prawn)} = \frac{1}{n-1} \times 300.1539 = 6.12559$$

$$s_{tb}^2 \text{(Total catch)} = \frac{1}{49} \times 338.48 = 6.9078$$

$$\left(\frac{1}{n} - \frac{1}{M}\right) s_{tb}^2$$

$$\text{For prawn} = \left(\frac{1}{50} - \frac{1}{150}\right) \times 6.1259 = 0.08167.$$

$$\text{For total catch} = \left(\frac{1}{50} - \frac{1}{150}\right) \times 6.9078 = 0.0921.$$

APPENDIX-VII

Calculation within sum of squares

Sl.No.	$\frac{1}{m_i} - \frac{1}{M_i}$	S_i^2		$(M_i/\bar{M})^2 \times (\frac{1}{m_i} - \frac{1}{M_i}) \times S_i^2$	
		Prawn	Total catch	Prawn	Total catch
1	2	3	4	5	6
1	0.225	4.5763	4.8878	0.5139	0.5492
2	0.1787	1.5030	1.5787	0.1852	0.1945
3	0.2230	0.8773	0.9418	0.0836	0.0897
4	0.18	0.06308	0.0468	0.0089	0.0066
5	0.0817	0.7999	0.9551	0.2424	0.2894
6	0.225	6.5333	7.0159	0.7342	0.7884
7	0.1787	3.9620	4.0588	0.4882	0.5001
8	0.2230	4.6642	4.9642	0.4445	0.4731
9	0.18	2.9421	3.2212	0.4133	0.4525
10	0.0817	1.4333	1.4298	0.4343	0.4332
11	0.225	7.745	8.0606	0.8703	0.9058
12	0.1787	0.61825	0.6892	0.0525	0.0586
13	0.223	0.0293	0.0389	0.00279	0.0037
14	0.18	7.1650	7.659117	1.0065	1.0759
15	0.0817	1.6164	1.6466	0.4898	0.4989
16	0.225	3.9506	4.4742	0.4439	0.5028
17	0.1787	14.2714	15.2753	1.7586	1.8823
18	0.223	2.6106	2.7206	0.2488	0.2593
19	0.18	2.9120	2.8480	0.4091	0.4001
20	0.0817	2.2841	2.5353	0.6921	0.7682
21	0.225	0.1346	0.1322	0.0151	0.0149
22	0.1784	0.3403	3.6625	0.0419	0.4506
23	0.223	1.4275	1.5108	0.6100	0.1859
24	0.18	0.4354	0.50108	0.0612	0.0704
25	0.0817	0.5571	0.5780	0.1688	0.1751

Contd........

1	2	3	4	5	6
26	0.225	2.0673	2.3342	0.2323	0.2623
27	0.1787	0.1505	0.18883	0.0186	0.0233
28	0.223	3.5825	4.2056	0.3414	0.4008
29	0.18	0.9631	1.0739	0.1353	0.1509
30	0.0817	0.4267	0.4631	0.1293	0.1403
31	0.225	0.7067	1.0989	1.1017	0.1235
32	0.1784	0.8304	1.6090	0.2027	0.1979
33	0.223	0.6537	1.2659	0.1540	0.1206
34	0.18	0.8834	0.067	0.0097	0.0096
35	0.0817	1.9258	0.5147	0.1344	0.1559
36	0.227	0.7067	0.1317	0.0154	0.0148
37	0.1787	0.8304	0.8075	0.0363	0.0995
38	0.223	0.6537	1.009	0.0866	0.1811
39	0.18	0.8534	0.2507	0.0265	0.0352
40	0.0817	1.9258	1.0087	0.2611	0.3056
41	0.225	0.7067	0.6423	0.1482	0.0722
42	0.1787	0.8304	2.353	0.2892	0.2899
43	0.223	0.6537	0.1629	0.0117	0.0155
44	0.18	0.8834	0.4025	0.0542	0.0565
45	0.0817	1.9258	0.7823	0.0422	0.0543
46	0.225	0.7067	0.0887	0.0086	0.0099
47	0.1787	0.8304	0.3918	0.0385	0.0483
48	0.223	0.6537	0.2352	0.0171	0.0224
49	0.18	0.8834	0.533	0.626	0.0749
50	0.0817	1.9258	0.8262	0.0465	0.0573
Total				13.2439	13.8816

Calculation of within sum of squares

$$\sum_{i=1}^{n} (M_i/\bar{M})^2 \left(\frac{1}{m_i} - \frac{1}{M_i}\right) s_i^2$$

For prawn $= 13.2439$

For total catch $= 13.8816$

$$\frac{1}{nN} \sum_{i=1}^{n} (M_i/\bar{M})^2 \left(\frac{1}{m_i} - \frac{1}{M_i}\right) s_i^2 =$$

For ptawn $= \frac{13.2439}{2830} = 0.004679$

For total catch $= \frac{13.8816}{2830} = 0.00491$

Calculation of standard error

$$V(\bar{Y}_s) = \left(\frac{1}{n} - \frac{1}{N}\right) s_{tb}^2 + \frac{1}{m.N} \sum_{i=1}^{n} (M_i/\bar{M})^2 \times \left(\frac{1}{m_i} - \frac{1}{M_i}\right)$$

$V(\bar{Y}_s)$ For prawn $= 0.08167 + 0.004679 = 0.086354.$

$SE(\bar{Y}_s) = \sqrt{V(\bar{Y}_s)} = \sqrt{0.086354} = 0.2938.$

For total catch $= (\bar{Y}_s) = 0.0921 + 0.00491 = 0.097$

$SE(\bar{Y}_s) = \sqrt{V(\bar{Y}_s)} = \sqrt{0.097} = 0.311.$

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